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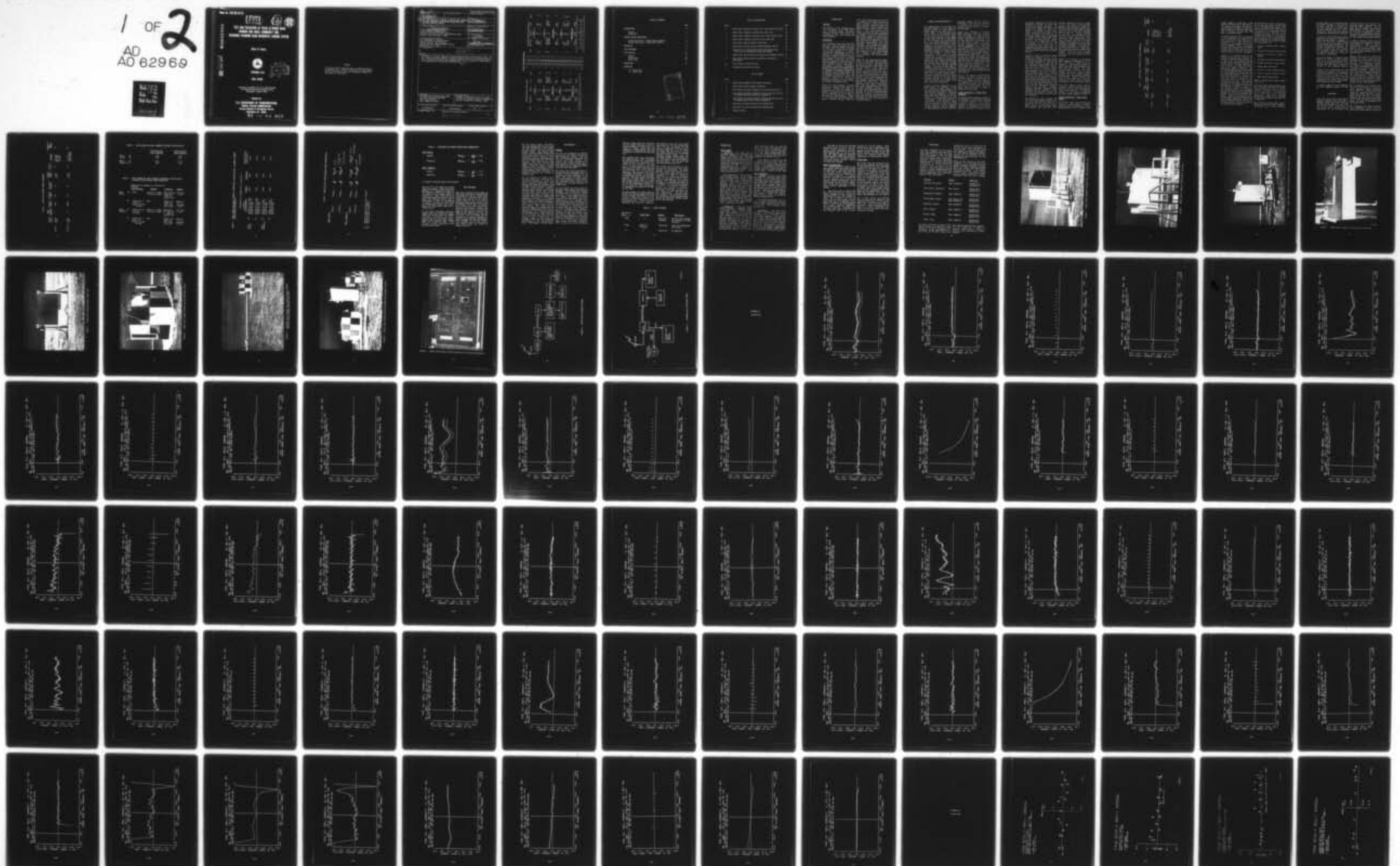

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TEST AND EVALUATION OF PHASE III BENDIX BASIC NARROW AND SMALL COMMUNITY TIME REFERENCE SCANNING BEAM MICROWAVE LANDING SYSTEM

Clifford W. Mackin

DEPARTMENT OF TRANSPORTATION • UNITED STATES OF AMERICA

NOVEMBER 1978

FINAL REPORT

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16. Abstract

Two models of the Time Reference Scanning Beam Microwave Landing System (MLS), the Basic Narrow and Small Community systems designed and built by the Bendix Corporation to FAA specifications, were examined with regard to functional requirements, and compliance with contractual specifications.

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METRIC CONVERSION FACTORS

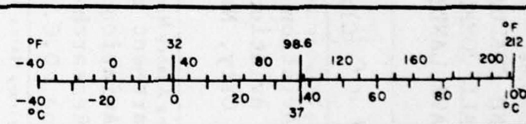
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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INTRODUCTION

PURPOSE.

The purpose of this program was to test two models of the Time Reference Scanning Beam, Microwave Landing System (TRSB MLS) for conformance with the contractual specifications.

BACKGROUND.

In accordance with the National Plan for the Development of the Microwave Landing System, published in July 1971, the United States (U.S.) MLS program is a joint, interservice Department of Transportation (DOT)/Department of Defense (DOD)/National Aviation and Space Administration (NASA) development activity, with DOT Federal Aviation Administration (FAA) designated as the lead agency. The National Plan initiated a three-phase, multiyear development program to identify and demonstrate a new approach and landing system which is intended to eventually replace the instrument landing system (ILS), and is designed to meet both civil and military operational needs as stated by SC-117 of the Radio Technical Commission for Aeronautics (RTCA) in December 1970.

Phase I of the program involved technique analysis and contract definition. During this phase, it appeared that both the TRSB and Doppler techniques had the potential for meeting the full range of operational requirements. Phase II, the feasibility demonstration phase, involved design, fabrication, and demonstration of both the Doppler and TRSB techniques using systems installed at the FAA's National Aviation Facilities Experimental Center (NAFEC) and NASA's Wallops Island test facilities. The test results from Phase II were thoroughly analyzed in December 1974 by an interservice government committee with full-time participation of international MLS experts from Australia, France, and the United Kingdom (U.K.) and part-time participation from other countries. This committee selected the TRSB technique over the Doppler technique for further development and, as a result, the TRSB system was submitted to the International Civil Aviation Organization (ICAO) as a candidate for international adoption.

Phase III was concerned with fabrication of prototype TRSB equipment in the different configurations necessary to show compliance with the requirements of all major user groups. One of these configurations is representative of a system intended to serve the majority of civil airports and is called the Basic Narrow Aperture system. Another is the most economical of the systems and is intended for short-runway operations, typically general aviation and airports associated with small communities. Thus, the configuration is called the Small Community system. Both systems were designed and manufactured by Bendix Communications Division, et al. It is to be noted that two similar configurations designed and developed by Texas Instruments will be covered in a separate report.

GENERAL SYSTEM DESCRIPTION

All configurations of the Phase III TRSB MLS (which is an air-derived system) operate at C-band (5031.0 - 5090.7 MHz) in the microwave frequency range. An air-derived system is one in which the aircraft position in space relative to the runway surface and centerline is determined by the airborne receiver/processor. This angle measurement is made relative to the horizontal plane tangent to the runway surface at the glidepath intercept point (GPIP) for elevation, and the vertical plane extending through the runway centerline for azimuth. In the TRSB technique, the airborne angle information is derived by precisely timing the passage of narrow fan beams which are scanned sequentially TO-FRO at high velocities through the azimuth and elevation coverage volume. The time interval between passage of the TO and FRO beams is directly proportional to the azimuth or elevation of the receiver and therefore the approach aircraft. Both of the subject systems have a transmitter power output of 20 watts and are required to provide usable guidance signals to a range of at least 20 nautical miles (nmi) in the most severe rain conditions.

Azimuth antenna beamwidth is the major factor in tailoring a system to a particular runway length. The distance from the azimuth antenna to the landing threshold is specified such that one beamwidth is approximately 300 feet (91 meters) in the lateral or cross-runway direction. For example, the threshold of a 5,000-foot (1,524 meters) runway would be nominally 6,000 feet (1,829 meters) from the 3° Small Community azimuth subsystem, and one beamwidth is approximately 300 feet laterally. The same lateral distance yields a 9,000-foot (2,743 meters) threshold to azimuth site distance for a 2° antenna such as used in the Basic Narrow system.

Large (e.g., 50-foot or 15-meters high) vertical reflecting surfaces such as hangars or other ground-support buildings are required by the current obstructions criteria to be at least 850 feet (260 meters) from an instrument runway. If this lateral separation represents several beamwidths (i.e., more than two beamwidths) of the azimuth antenna, no inbeam multipath from these sources will be generated in the centerline approach region. Observing the "300 foot" rule when siting the azimuth subsystem will insure more than two beamwidths separation and the centerline region will be free of inbeam reflections from vertical reflectors. The systems have been designed to reject out-of-beam multiplath so no consideration of this phenomenon is necessary when considering system installation.

One of the design considerations operative in both of these systems is the concept of modularity, in which the system can be configured or upgraded to suit the changing needs of a particular user by adding additional subsystems such as flare, missed approach, or range as needed at a later time.

SYSTEM DESCRIPTION - BENDIX SMALL COMMUNITY.

The Bendix Small Community system is a prototype of the system intended to provide (approach and landing guidance) service in a low-cost package to relatively short runways typical of low-density feeder and general aviation airports, while

retaining compatibility with more expanded versions of TRSB and allowing for growth potential. The system error budget and monitor are designed to support at least category I instrument flight rules (IFR) operations (200 feet or 61 meters ceiling, and 2,400 feet or 732 meters runway visual range (RVR) on runways up to 5,000 feet (1,524 meters). The Bendix Small Community system is comprised of two subsystems, an azimuth unit and an elevation unit. Each unit is completely self-contained within its climate-controlled antenna case and does not require additional equipment shelters.

Figure 1 shows the Bendix Small Community azimuth unit as it was installed at NAFEC serving runway 8. The mounting support configuration is clearly visible, as well as the main scanning antenna radome and the two sidelobe suppression antenna radomes on each forward corner. Tall (7-feet or 2 meters high) mounting poles allow line of sight to the touchdown zone over a slight "hump" in the runway. Figure 2 is a rear view of the azimuth unit with the electronics access panel removed, showing the electronics rack on the left, antenna and maintenance access panels in the center and right, and the sidelobe suppression antenna radome on the far right. Though a distance measuring equipment (DME) subsystem was not included in this hardware configuration, space for this option has been provided within the enclosure.

The azimuth unit uses a Rotman lens with 46 output elements spaced so as to form a vertical fan beam 3° in width and 20° in elevation with a sharp cutoff on the bottom edge. This antenna scans from left 12.5° through centerline (C/L) to right 12.5°, providing proportional guidance from left 10° to right 10°. Built-in sector antennas provide full fly-left and full fly-right coverage from left 40° to left 10°, and right 40° to right 10°. Similar antennas provide for identification and out-of-coverage indication (OCI) functions. The elevation unit also uses a Rotman lens with 46 output elements, but spaced so as to form a horizontal fan beam 2° in width with an H-plane coverage of from left 40°, through centerline, to right 40°. Scan coverage provides proportional guidance from 1° to 15.° in elevation. A built-in sector antenna provides for the identification function.

Figure 3 is a picture of the Bendix Small Community elevation unit as it was installed at NAFEC serving runway 8. The mounting support is shown along with the antenna access panel and both radomes. The scanning antenna is under the left radome, while the right radome covers the sector identification antennas and the sidelobe suppression antenna. Figure 4 shows a rear view of the same unit with the electronics access panel removed, displaying the electronics rack.

Both units employ a dual internal integral system monitor and an external accuracy and radiofrequency (RF) field monitor. A tabular summary of the antenna parameters for each system appears in table 1.

SYSTEM DESCRIPTION - BENDIX BASIC NARROW.

The Bendix Basic Narrow Aperture system is a prototype of a representative system intended for use in medium-density civil airports with

TABLE 1. BENDIX SMALL COMMUNITY MLS SUMMARY PARAMETERS

	Antenna Type	Beam-width (Degrees)	Frequency (MHz)	Wavelength (CM)	No. Output Elements	Element Spacing (CM)	Aperture (λ)	Coverage	Transmitter Power (Watts)
Azimuth	Rotman lens	3	5090.1	5.89	46	2.96 (0.502)	23	$\pm 10^\circ$ proportional 10° - 40° clearance 0° - 20° E-plane	20
Elevation	Rotman lens	2	5090.1	5.89	46	4.44 (0.754)	35	1° - 15° proportional $\pm 40^\circ$ H-plane	20

runway lengths of 5,000 feet (1,524 meters) to 8,000 feet (2,438 meters). The system error budget and monitoring system are designed to support at least category II IFR operations (100 feet or 30 meter ceiling, and 1,200 feet or 366 meters RVR.)

The Bendix Basic Narrow is comprised of two subsystems, an azimuth unit with precision L-band DME and an elevation unit. Each subsystem consists of an antenna with a separate equipment shelter containing the MLS RF electronics. The azimuth shelter also houses the precision L-band DME and contains the data/identification and OCI antennas.

Figure 5 is a frontal view of the Bendix Basic Narrow azimuth installed at NAFEC serving runway 13. In this view, the scanning antenna radome and the mounting supports are clearly seen. A close-up picture of the azimuth and DME equipment shelter is shown in figure 6. The two antenna radomes on the left face of the building contain, from left, the identification antenna and the precision DME antenna. One of the rear OCI antennas is visible on the right face of building, the other being out of sight on the building's far side. The azimuth antenna and equipment shelter are separated by a distance of 200 feet (61 meters) as shown in figure 7. The C-band signal is generated and amplified within the equipment shelter and sent to the transmitting antenna via a buried elliptical wave guide. Monitor electronics and a control console are also housed here. The building immediately behind the azimuth antenna was built for use on a previous project and is not part of the Basic Narrow equipment.

The Bendix Basic Narrow radiates the basic data functions as provided for in the TRSB signal format. This allows digitized data applying to the specific siting and system conditions to be uplinked to the airborne receiver via the sector antenna and decoded for presentation to the pilot or use in the receiver. Data transmitted by the Bendix Basic Narrow presently linked through the data channel are:

1. Facility identification - (Morse Code)
2. Minimum Selectable Glide Slope
3. Elevation Antenna Offset & Height
4. Elevation Ground System Status
5. Azimuth Deviation Scale Factor
6 Range, DME to Elevation
7 Azimuth Ground System Status
8 Flare Ground System Status
9 DME Ground System Status

(Source: Bendix final report, pages 2-33, 2-34.)

The Bendix Basic Narrow azimuth unit uses a Rotman lens with 64 output elements spaced so as to form a vertical fan beam 2° in width and 20° in elevation. This antenna scans from left 41.7° through centerline to right 41.7°, providing proportional guidance from left 40° to right 40°.

The elevation system also uses a Rotman lens with 64 output elements, but spaced so as to form a horizon-

tal fan beam 1.5° in width and with an H-plane coverage of from left 40° through centerline to right 40°. The scan coverage provides proportional guidance from 1° to 15° in elevation. A built-in sector antenna provides the identification function.

A picture of the Bendix Basic Narrow elevation antenna as installed at NAFEC serving runway 13 appears in figure 8. The left radome houses the scanning beam antenna and the forward identification antenna. The sidelobe suppression antennas are housed beneath the other radome. The equipment shelter houses the C-band RF transmitter, monitor, and control electronics.

Both units employ an external field monitor to monitor system performance, and a microprocessor-controlled maintenance monitor with cathode-ray tube (CRT) display is located in each equipment shelter.

Figure 9 is a photograph of the azimuth transmitter and monitor electronics inside the equipment shelter shown in figure 8. The elevation console has a similar configuration, and many of the components are directly interchangeable between the two systems.

A tabular summary of the parameters for each subsystem appears in table 2.

OBJECTIVES

Both the Basic Narrow and Small Community systems were subjected to numerous flight and static tests as required by the Phase III test plan for the U.S. MLS. The object of these tests was to provide data to determine if the systems were operating within the accuracy and coverage limits specified by the Phase III TRSB contracts. For the Basic Narrow system, specification FAA-ER-700-01 is applicable, while for the Small Community system, specification FAA-ER-700-04 applies. Allowable degradation factors appear in specification FAA-ER-700-07.

A tabular listing of the required accuracies and allowable degradations appears in tables 3, 4, and 5, respectively. The degradation factors for path-following error (PFE) and control motion noise (CMN) are expressed mathematically in tables 6 and 7.

Angular error is the difference between the angle received and processed by the airborne receiver and the true angle at the same instant. The guidance signals are subject to propagation distortion and processing inaccuracies introduced in both the ground and airborne equipment. These errors fall into two categories,constant bias errors and cyclical errors of all frequencies. These errors interact with the aircraft flight control system in a variety of ways, resulting in two general types of guidance errors, PFE and CMN.

PFE encompasses the steady-state bias and low-frequency cyclical error components whose frequencies lie in the 0 to 1 radian per second range for elevation and 0 to 0.5 radian per second range for azimuth. These errors are of a low enough frequency for the aircraft to physically track and have a measurable effect in terms of deviations from the desired track.

CMN encompasses the higher frequency error components in the 0.5 to 10 radian per second range for elevation

TABLE 2. BENDIX BASIC NARROW SUMMARY PARAMETERS

	Antenna Type	Beam-width (Degrees)	Frequency (MHz)	Wavelength (CM)	No. Output Elements	Element Spacing (CM)	Aperture (λ)	Coverage	Transmitter Power (Watts)
Azimuth	Rotman lens	2	5060.7	5.92	64	3.20 (0.54)	35	$\pm 40^\circ$ proportional $0^\circ - 20^\circ$ E-plane	20
Elevation	Rotman lens	1.5	5060.7	5.92	64	4.26 (0.719)	46	$1^\circ - 15^\circ$ proportional $\pm 40^\circ$ H-plane	20

TABLE 3. BASIC NARROW AND SMALL COMMUNITY ACCURACY SPECIFICATIONS

		Path-Following Error (Degrees)	Control Motion Noise (Degrees)
Basic	AZ	0.20	0.07
Narrow	EL	0.12	0.05
Small	AZ	0.33	0.10
Community	EL	0.16	0.10

TABLE 4. BASIC NARROW AND SMALL COMMUNITY CONTRACTUAL SPECIFICATION, ALLOWABLE PATH-FOLLOWING ERROR DEGRADATION

Degradation in degrees as a function of:

		Distance from Threshold	Azimuth	Elevation	Remarks
Basic Narrow	AZ	None	Linear to 2 times C/L error at ±60°	None below 9° Linear to 2 times C/L error at 20°	C/L error = 0.20°
	EL	Linear to 1.5 times 2.5° error at 20 nmi (37 km)	None	Linear to 3 times 2.5° error from 2.5° to 20°	Error at 2.5° on threshold = 0.12°
Small Community	AZ	Linear to 0.4° at 20 nmi (37 km)	Linear to 2 times C/L error at ±60°	None below 9° Linear to 2 times C/L error at 15°	C/L error = 0.33°
	EL	Linear to 1.5 times 2.5° error at 20 nmi (37 km)	None	Linear to 3 times 2.5° error from 2.5 to 15°	Error at 2.5° on threshold = 0.16°

TABLE 5. BASIC NARROW AND SMALL COMMUNITY CONTRACTUAL SPECIFICATION, ALLOWABLE CONTROL MOTION NOISE DEGRADATION

Degradation in degrees as a function of:

		Distance from Threshold	Azimuth	Elevation	Threshold Value at 2.5° G/S
Basic Narrow	AZ	Linear to 1.4 times threshold value at 20 nmi (37 km)	None	None	0.07
	EL	Linear to 1.4 times threshold value at 20 nmi (37 km)	None	None	0.05
Small Community	AZ	Linear to 2 times threshold value at 20 nmi (37 km)	None	None	0.10
	EL	Linear to 2 times threshold value at 20 nmi (37 km)	None	None	0.10

TABLE 6. EQUATIONS FOR PATH-FOLLOWING ERROR DEGRADATIONS

Basic Narrow

Azimuth: $$PFE_{(DEG.)} = \frac{Az}{380} + \frac{2EL - 18}{110} + 0.20 \qquad 9° \leq EL \leq 20°$$

Elevation: $$PFE_{(DEG.)} = \frac{3R}{1000} + \frac{24EL - 60}{1750} + 0.12 \qquad 2.5° \leq EL \leq 20°$$

Small Community

Azimuth: $$PFE_{(DEG.)} = \frac{7R}{1000} + \frac{11 \quad Az}{1000} + \frac{11EL - 99}{100} + 0.33 \qquad 9° \leq EL \leq 15°$$

Elevation: $$PFE_{(DEG.)} = \frac{12R}{1000} + \frac{48EL - 120}{1250} + 0.16 \qquad 2.5° \leq EL \leq 15°$$

R - Range in nautical miles from threshold
EL - Elevation angle in degrees
Az - Azimuth angle in degrees

TABLE 7. EQUATIONS FOR CONTROL MOTION NOISE DEGRADATIONS

Basic Narrow

Azimuth:	$CMN(DEG.) = \frac{1.4R}{1000} + 0.07$	
Elevation:	$CMN(DEG.) = \frac{R}{1000} + 0.05$	

Small Community

Azimuth	$CMN(DEG.) = \frac{R}{200} + 0.10$	
Elevation:	$CMN(DEG.) = \frac{R}{200} + 0.10$	

R = Range in nautical miles from threshold.

and the 0.3 to 10 radian per second range for azimuth. These errors are generally of a frequency too high for the aircraft to physically track, but low enough for the control system to respond to. Thus, CMN results in rapid small-amplitude control surface wheel and column motions, and is undesirable in that it contributes to control surface and servo wear and diminishes flight crew confidence by presenting them with a "shaky stick."

In the data analysis section, flight data are presented graphically as one plot each for azimuth raw data, elevation raw data, azimuth error, elevation error, azimuth PFE, elevation PFE, azimuth CMN, and elevation CMN. This allows a quick comparison with specification values.

TEST PROCEDURE

Data were collected in two ways: as static data collected by ground-based instrumentation and as flight data. Static data collection was accomplished with the use of an instrumented mobile test van with an adjustable antenna mast which could be extended to 50 feet (15 meters) while precisely positioned over surveyed test points. Flight data were collected with the use of NAFEC's DC6 (N46), Convair 580 (N49), Convair 880 (N42) as test bed aircraft, and the NAFEC phototheodolite tracking system for accurate space position information. Block diagrams of the data collection systems used in the static and flight tests are shown in figures 10 and 11.

For the static tests, the mobile test van antenna mast was positioned over each surveyed point and a sample of data taken for each desired antenna height. The digital angle output from the TRSB receiver was then interfaced with a General Automation SPC-16 computer which stored 66 continuous data samples and then performed statistical computations. The value of each data sample along with the error of each sample, population mean, standard deviation, and correlation coefficients were then transferred to a Hewlett-Packard 9830 calculator for graphical display and storage on cassette tape.

For the dynamic or flight tests, accuracy data were collected on a series of straight-in, level runs and straight-in approaches using azimuth and elevation guidance from the TRSB receiver driving a standard ID-248 cross-pointer display. Constant-radius orbital runs through the coverage volume were accomplished for both accuracy and coverage measurements using range guidance from the ACY VORTAC and barometric altitude. All flights were tracked by the NAFEC theodolite system which was time synchronized with the airborne data collection system. The tracker-derived position became the standard against which the TRSB-derived position was compared for the resulting accuracy and coverage data. Upon completion of the flight, the TRSB airborne tape was time merged with the tracker tape to determine the guidance errors over the flightpath according to the relationship: Error = RCVR Angle - Tracker Angle.

DATA ANALYSIS

GENERAL.

The data are presented as separate groups for the Basic Narrow and Small Community systems. The data for each system are separated into static and flight groups, with similar data being presented for each system to allow an easy comparison both with the system specifications and with each other.

The static data allow an estimate of system bias and instrument noise to be made. The bias measured in the static data would correspond to the PFE at that point in space, while the "noise" measured is the hardware and instrument noise, which is one component of the CMN estimated by flight tests.

For each system, the static data are separated into azimuth and elevation packages. Each azimuth data package is presented as a series of plots which are: (1) an azimuth cross-cut at a nominal 1-nmi range (the actual range is determined by physical accessibility) at a constant indicated elevation angle with respect to the azimuth site, (2) a vertical cut of the azimuth at centerline in the touchdown zone and, (3) a horizontal cut at a constant height (approximately the antenna height of a transport aircraft on rollout) along the runway centerline. For each elevation data package, the following plots are presented: (1) a horizontal cut at a constant elevation angle across the runway threshold, (2) a vertical cut at a nominal

500-foot range from the elevation site on runway centerline, and (3) a constant nominal 3° glide slope cut along the runway centerline from threshold to approximately 200 feet (61 meters) in front of the elevation site.

The flight data are separated by flight patterns. Both the azimuth and elevation data for a particular flight pattern are presented in a series of up to 10 plots. For each run, 5 of each series of 10 plots pertain to the azimuth subsystem, and the remaining five plots present similar data for the elevation subsystem. Each group of five plots is arranged as follows: (1) MLS angle receiver output and tracker reference position, (2) MLS angle error (MLS angle minus tracker angle), (3) mean and 2-sigma variation for each partition of the independent variable (1/3 nmi in range for radial approaches, 7° azimuth bins for orbits), (4) PFE, and (5) CMN.

For each system, the flight patterns plotted are similar enough within the system coverage limitations to allow a direct comparison between the systems and the previously listed specifications. The patterns displayed are listed in table 8.

The heading of each plot lists these pertinent data: (1) the system under test, (2) the subsystem, (3) the antenna beamwidth, (4) the date, (5) start time, (6) the X, Y, Z from the runway threshold to the azimuth antenna phase center, (7) the elevation antenna phase center and the DME antenna (if applicable), (8) theodolite solution (standard solution (SS)), (9) aircraft, and (10) description of the run.

The flight data are shown as collected and analyzed for three patterns on each system. The Basic Narrow flight data consist of a 3° centerline approach flown on September 23, 1977, a centerline level run at 2,000-feet altitude flown on September 1, 1977, and a partial orbit through the azimuth coverage at 2,000-feet altitude and a distance of 5 nmi flown on August 15, 1977. The Small Community flight data consist of similar patterns collected on April 11, 1977, April 13, 1977, and April 22, 1977, respectively. The data show each system to be operating within the previously listed specifications within the specified coverage volume for all the patterns.

TABLE 8. FLIGHT PATTERNS

Altitude in Feet	Glide Slope	Azimuth	Description
2,000	--	Entire Az Coverage	Partial orbit through Az coverage at a fixed Altitude
2,000	Entire El Coverage	Centerline	Level run terminating at Az site
----	3°	Centerline	Low Approach

FLIGHT DATA.

BASIC NARROW

Azimuth. For both the 3° approach (pages A-1 through A-5) and the 2,000-foot level overflight (pages A-11 through A-15), the PFE is well within the minimum specification limit of ±0.2° at all points without applying degradation factors. Likewise, the CMN is within the specification limit of ±0.07° at threshold degrading to ±0.077° at 5 nmi for both flightpaths. (See Flight Data Notes No. 2.)

The 2,000-foot, 5-nmi partial orbit through system coverage (pages A-21 through A-24) shows a PFE within ±0.25° with a CMN within ±0.077°. Since PFE is allowed to degrade from a centerline (0° azimuth) value of ±0.2° to a value of ±0.31° at either extremity of the ±40° scan, the system is well within specification values. The CMN limit at 5 nmi is ±0.077° and the system is within this limit except for single-point excursions. (See Flight Data Notes No. 2.) FAA-ER-700-07 allows the 2-sigma value to exceed the specification limit 5 percent of the time.

Elevation. For all three flight patterns, 3° approach (pages A-6 through A-10), 2,000-foot level overflight (pages A-16 through A-20), and 2,000-foot, 5-nmi partial orbit (pages A-25 through A-29), the PFE is well within the system minimum specifications of ±0.12° without applying any degradation factors. It should be noted that on the level overflight, all elevation radials within system coverage are intercepted, and that since the allowable PFE degrades with increasing elevation (table 6), the PFE would be within specification even if the data shown on page A-19 were of twice their actual amplitude; i.e., the system demonstrates performance exceeding this specified parameter by a factor of two.

The system is within the CMN minimum specification limit of ±0.05° for all three flight patterns except for isolated single-point values. FAA-ER-700-07 allows the 2-sigma value to exceed the specification limit 5 percent of the time.

SMALL COMMUNITY.

Azimuth. For all three flight patterns, 3° approach (pages A-30 through A-34), 2,000-foot level overflight (pages A-40 through A-44), and 2,000-foot, 5-nmi partial orbit through system coverage (pages A-50 through A-52), the PFE is well within the minimum specified value of ±0.33° without applying any degradation factors. This demonstrated performance places it within the tighter, specification limits of the Basic Narrow system (±0.20°).

The CMN demonstrated for all three flight patterns is within the minimum specification value of ±0.10°. (See Flight Data Notes No. 2).

Elevation. For all three patterns, 3° approach (pages A-35 through A-39), 2,000-foot level overflight (pages A-45 through A-49), and 2,000-foot, 5-nmi partial orbit (pages A-53 through A-57), the PFE is well within the minimum specified value of ±0.16° without applying degradation factors. Again, the performance demonstrated is within the tighter Basic Narrow system specifications (±0.12°).

The CMN is within the minimum specified value of $\pm0.1°$ for all three flight patterns without applying any degradation factors. Upon examination, it can be seen that the Small Community elevation system performs within the specification limits of the Basic Narrow elevation system ($\pm0.05°$) within its specified coverage.

NOTES ON FLIGHT DATA.

1. System biases are shown on all data except those data passed though the CMN filter. Data were displayed in this way rather than with the bias removed so as to demonstrate a worst-case condition. In actual practice, the bias of each subsystem can be removed quite easily by several system adjustments, which would result in the virtual elimination of all bias and show a subsequent further improvement in PFE values.

2. The filter used to extract CMN data from the raw error data is a digital bandpass filter necessarily initialized at the first sample of data. By its nature, this filter should have no bias output, and the mean value of an increasingly large number of samples is indeed asymptotic to zero. However, immediately upon initialization, the sample size is small, and this, combined with the response time of the filter, yields an initial bias. Upon inspection of the accompanying data, it is seen that the first few samples of data produced by the CMN filter contain the bias factor and should be ignored when making comparisons to specification values.

STATIC DATA.

The static data are shown as collected and analyzed for three types of presentations for each subsystem (pages B-1 through B-12). The azimuth plots depict an azimuth cross-cut, a simulated rollout down runway centerline, and a vertical probe in the touchdown region. The plots for elevation show an azimuth cross-cut, a simulated 3° centerline approach, and a vertical probe in the threshold region. The system mean error at each point would correspond to the PFE at that point in space, while the 2-sigma "noise" value would be a component of the CMN shown in the flight data. The data show both systems to be operating within specification at all points.

For a visual check, the vertical axis of each plot is limited at the specified PFE value of the system under test. The data were taken at precisely located surveyed points whose X, Y, and Z coordinates relative to the site under test were accurately surveyed.

CONCLUSIONS

The data displayed in this report have been compared with specifications written by the FAA for these particular systems. Also, the data were obtained under controlled conditions without severe multipath. However, both systems have been demonstrated in various operational situations at selected active airports both in the U.S. and abroad. The following listing covers the system demonstrations and summary reports to date that have been accomplished at operational airports other than NAFEC:

Location	System	Report No.
Cape May, New Jersey	Small Community	FAA-RD-78-13 FAA-NA-78-13
Buenos Aires, Argentina	Basic Narrow	FAA-RD-78-14 FAA-NA-78-14
Tegucigalpa, Honduras	Small Community	FAA-RD-78-15 FAA-NA-78-15
Kristiansand, Norway	Basic Narrow and Small Community	FAA-RD-78-17 FAA-NA-78-17
Charleroi, Belgium	Small Community	FAA-RD-78-19 FAA-NA-78-19
Dakar, Senegal	Small Community	FAA-RD-78-21 FAA-NA-78-21
Nairobi, Kenya	Small Community	FAA-RD-78-22 FAA-NA-78-22
Shiraz, Iran	Small Community	FAA-RD-78-23 FAA-NA-78-23

The data collected at these field demonstrations are compared in each report to the more stringent Full Capability System Specification as set forth by the ICAO. These error limits are $\pm 0.1°$ in elevation and $\pm 0.076°$ in azimuth and apply to the raw data. Both systems, which were meant to actually conform to the ICAO Reduced Capability Configuration, met or exceeded the Full Capability specifications in all demonstrations.

Based on the results of the tests conducted, it is concluded that the guidance signals from both the Basic Narrow and Small Community systems were well within the contractual specification limits. It is further concluded that the reduced capability Small Community system performed within the more stringent Basic Narrow specifications, indicating the capability of TRSB to provide high-quality guidance signals with economical system hardware.

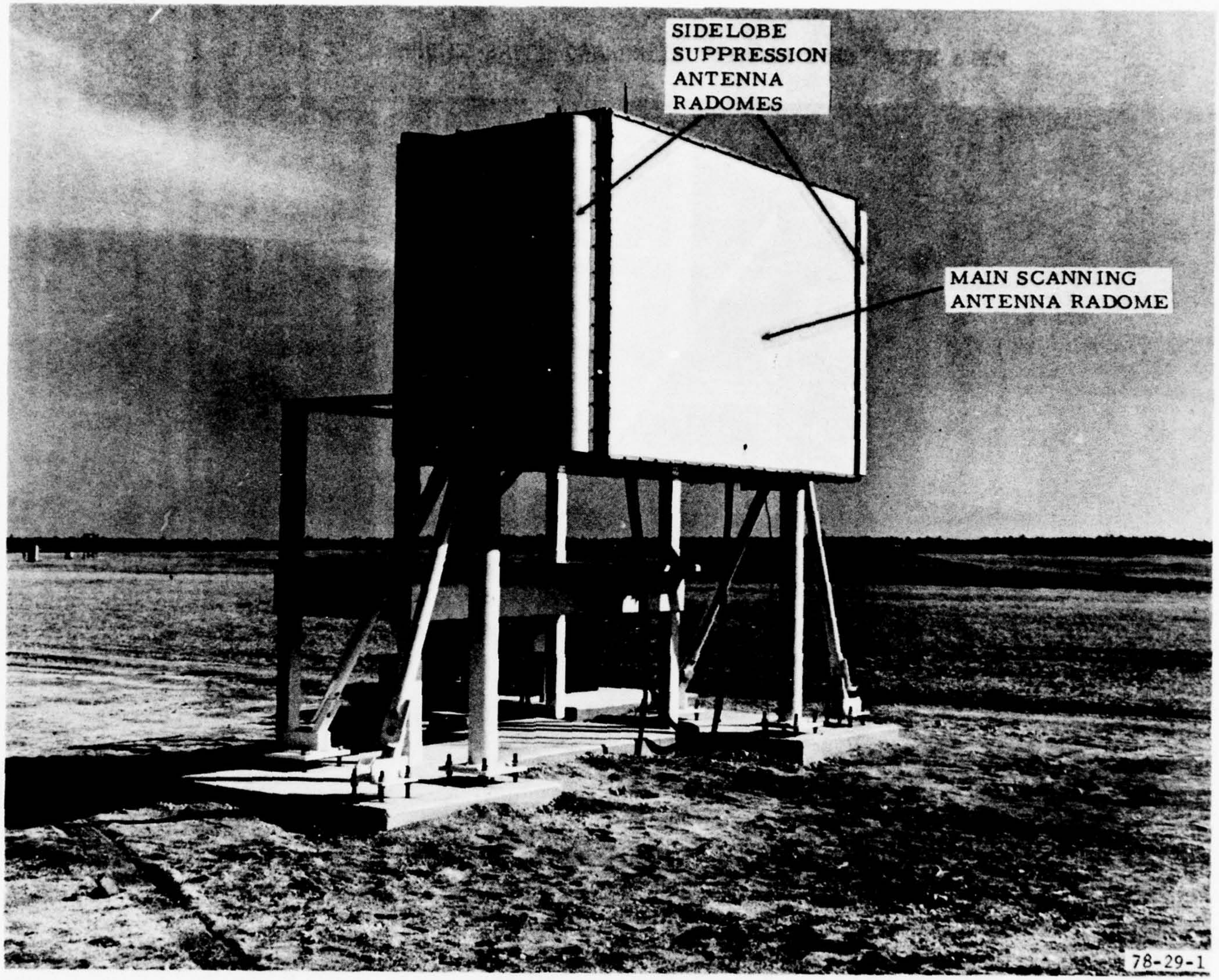


FIGURE 1. BENDIX SMALL COMMUNITY AZIMUTH UNIT, FRONT QUARTERING VIEW

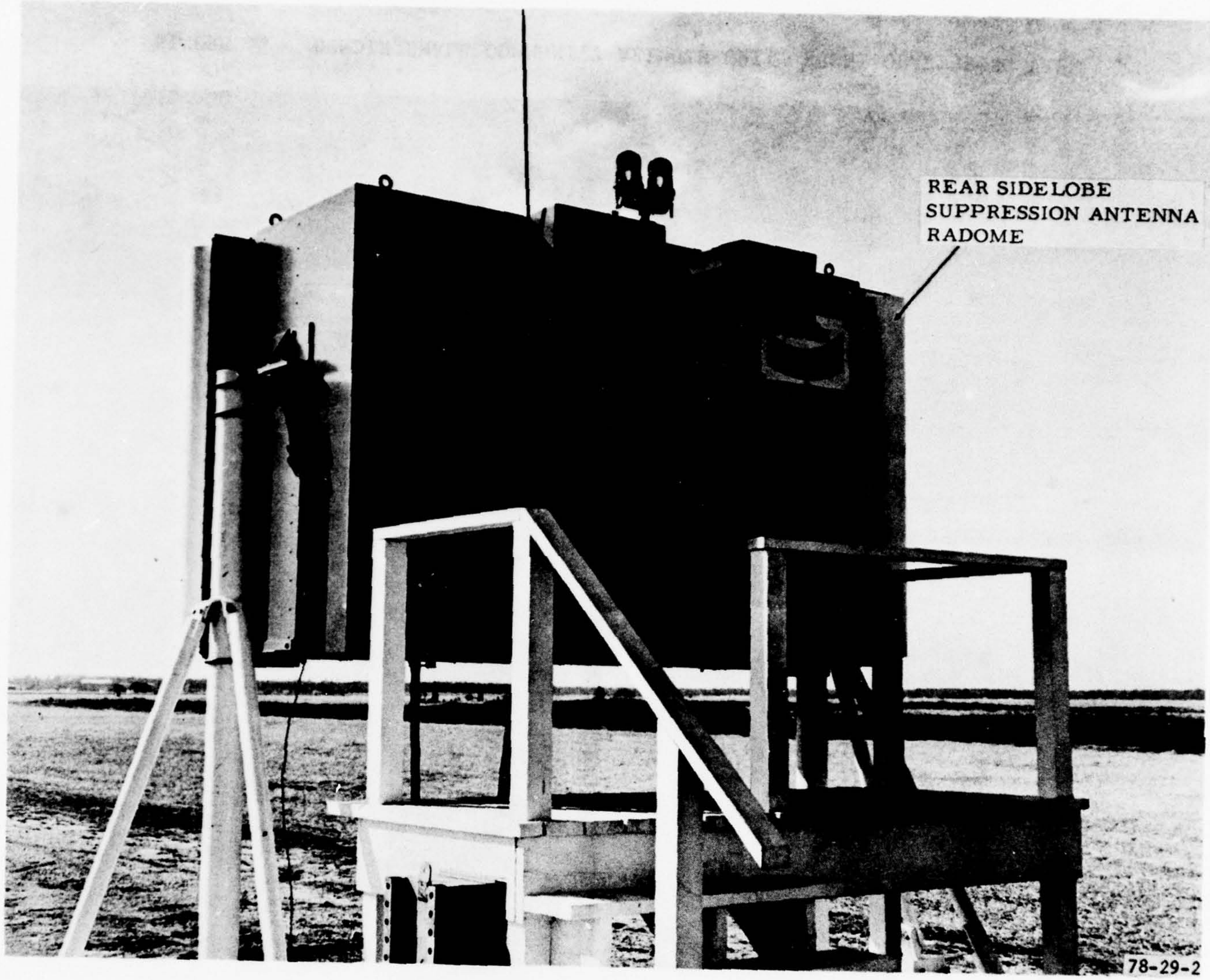


FIGURE 2. BENDIX SMALL COMMUNITY AZIMUTH UNIT, REAR VIEW

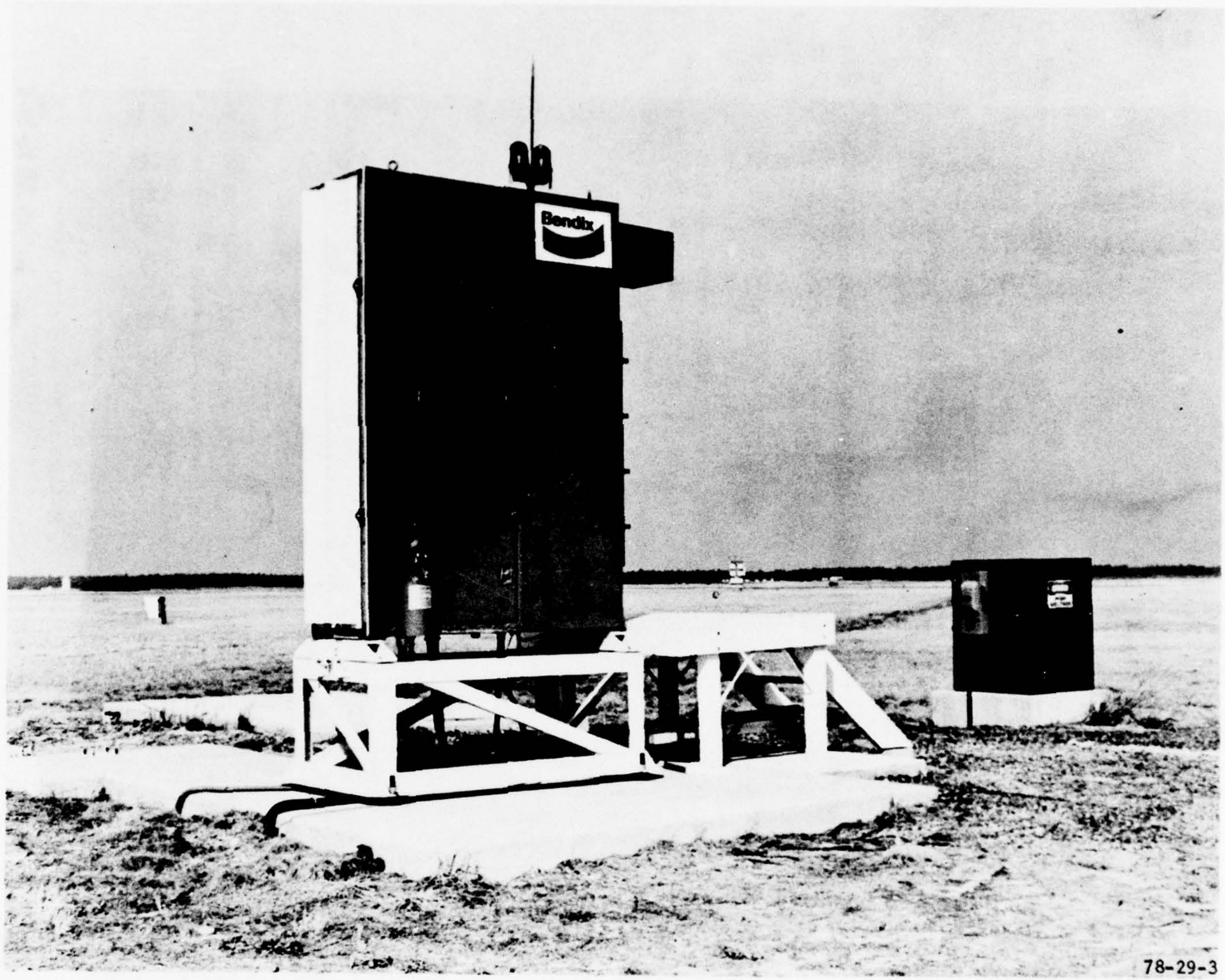


FIGURE 3. BENDIX SMALL COMMUNITY ELEVATION UNIT, FRONT QUARTER VIEW

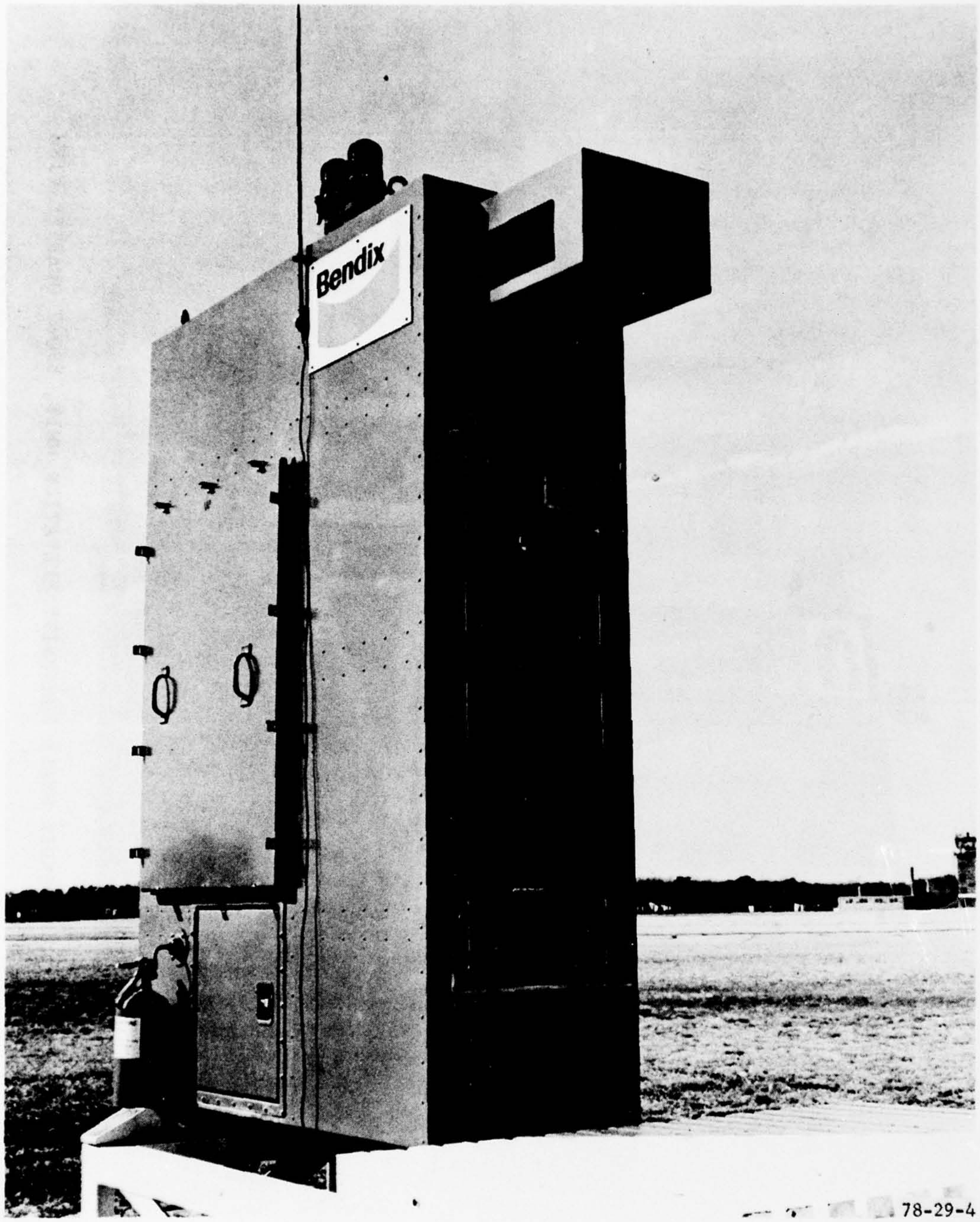


FIGURE 4. BENDIX SMALL COMMUNITY ELEVATION UNIT, REAR VIEW

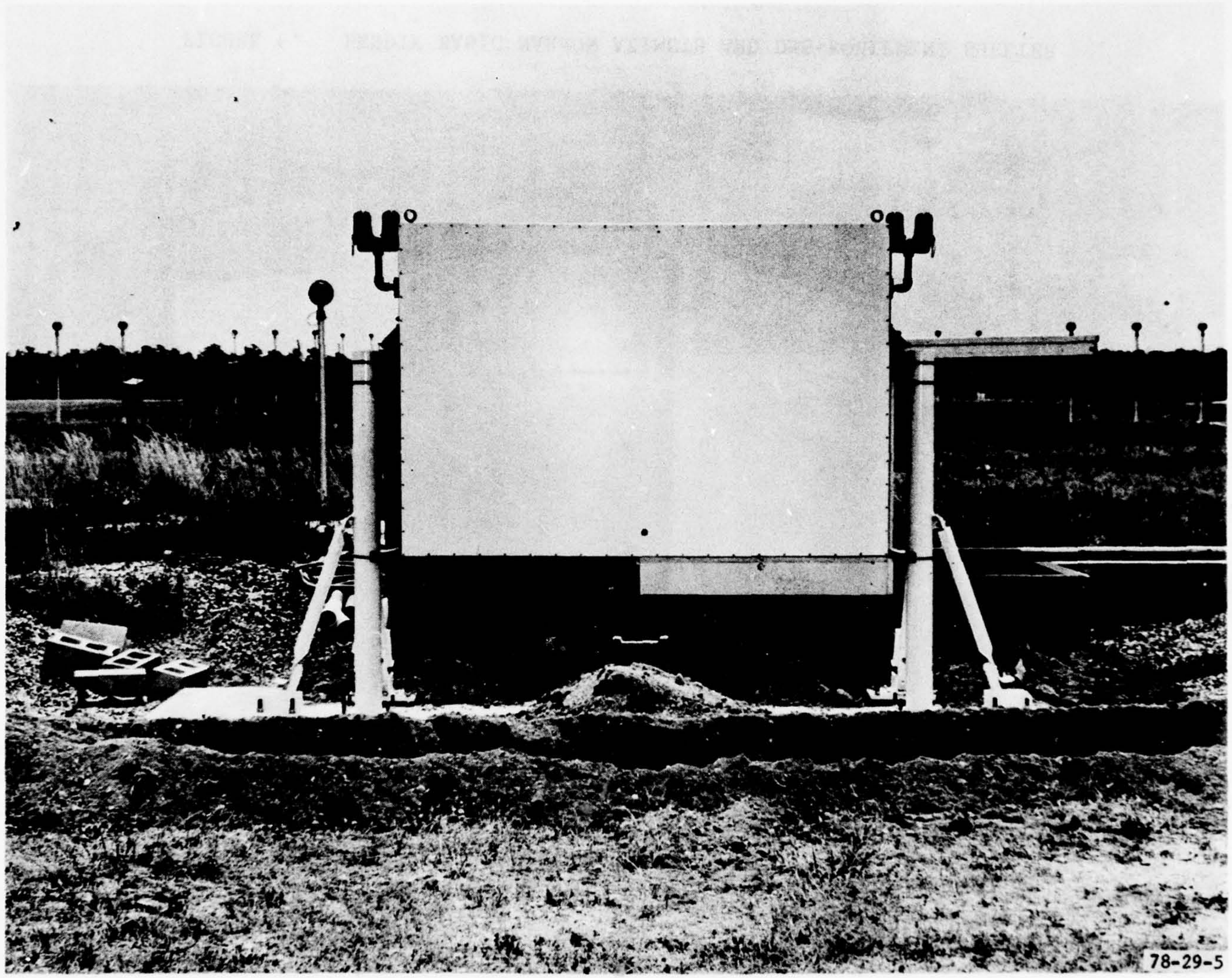


FIGURE 5. BENDIX BASIC NARROW AZIMUTH, FRONT VIEW

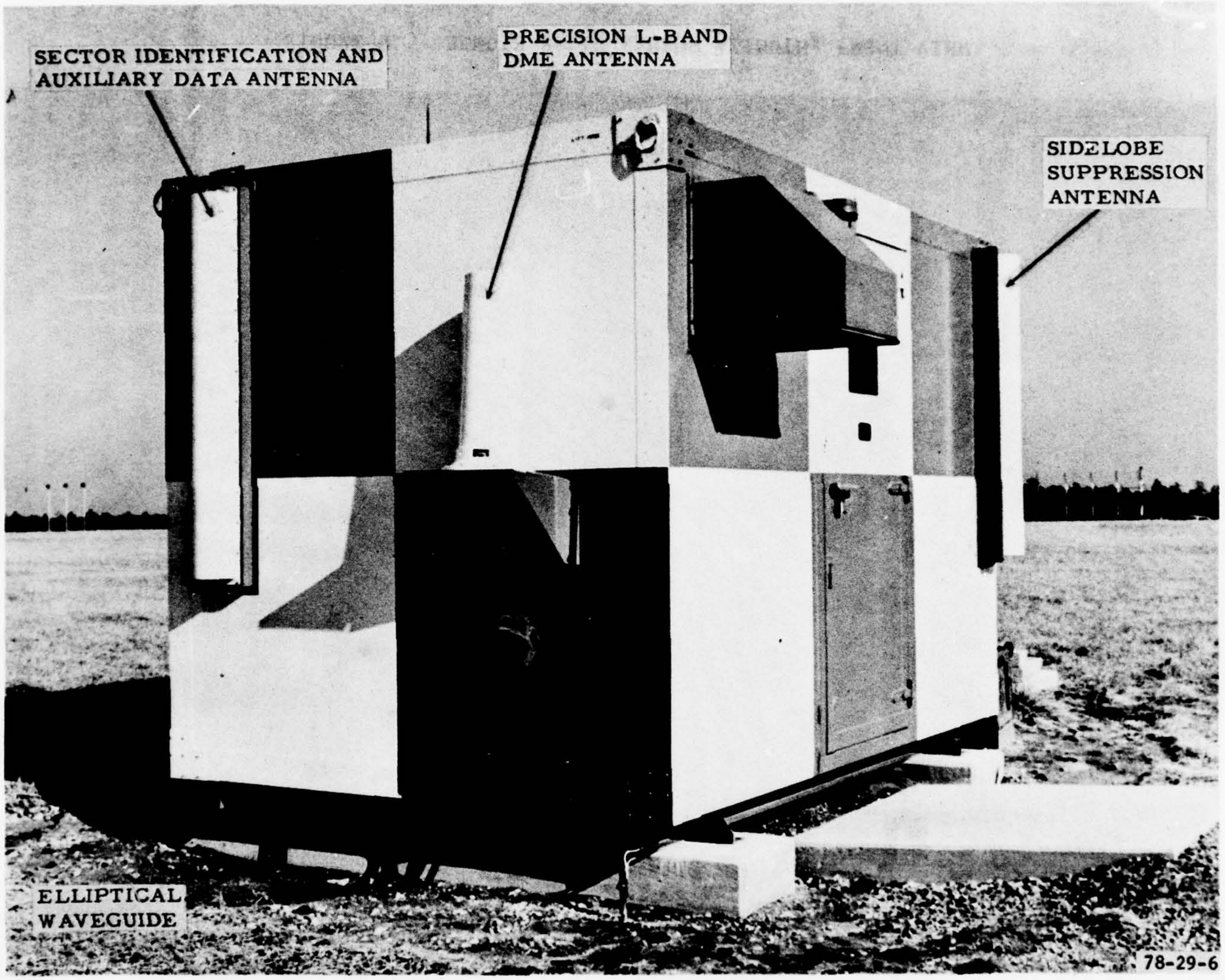


FIGURE 6. BENDIX BASIC NARROW AZIMUTH AND DME EQUIPMENT SHELTER

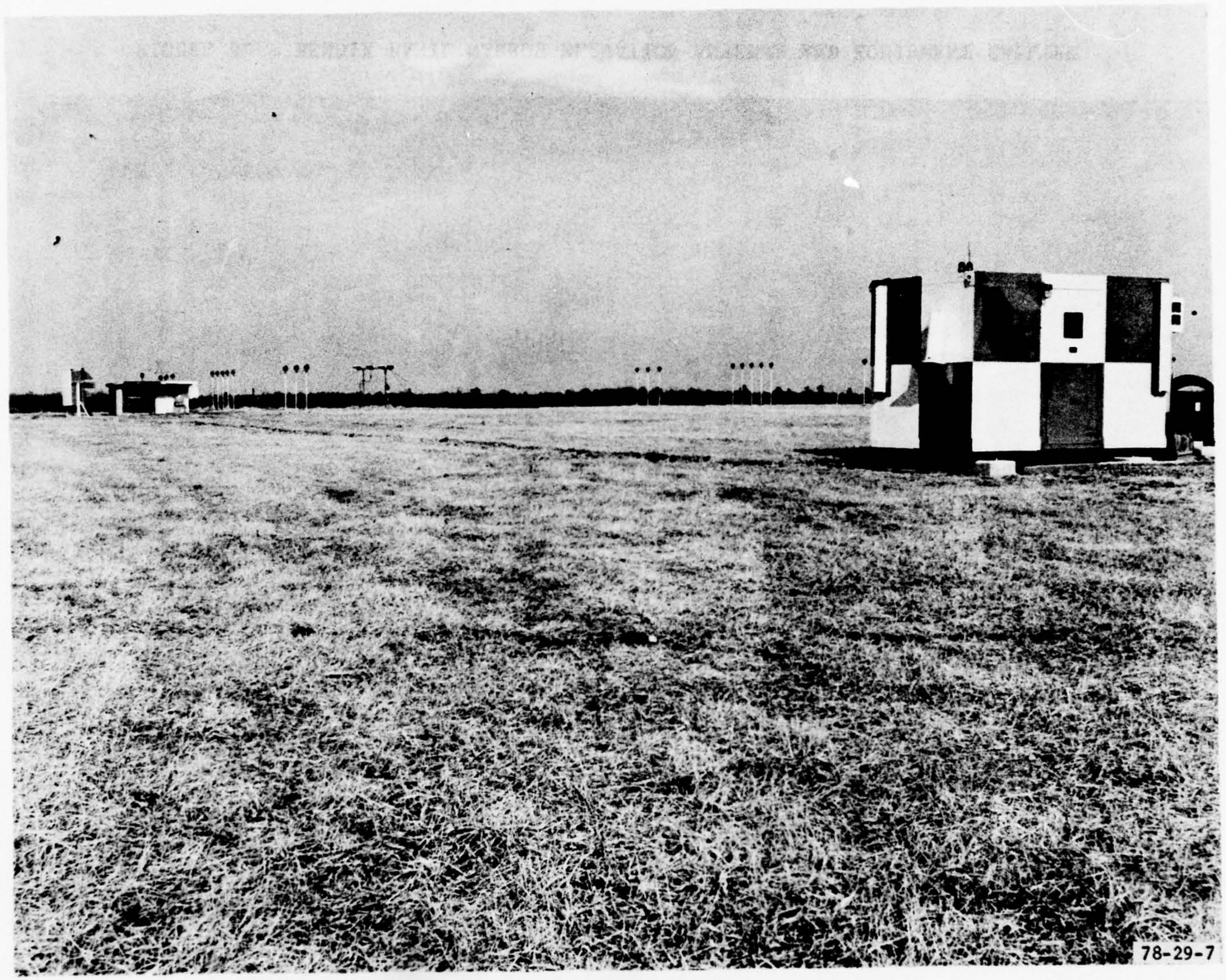


FIGURE 7. COMBINED VIEW OF BENDIX BASIC NARROW AZIMUTH ANTENNA (FAR LEFT) AND EQUIPMENT SHELTER (FAR RIGHT)

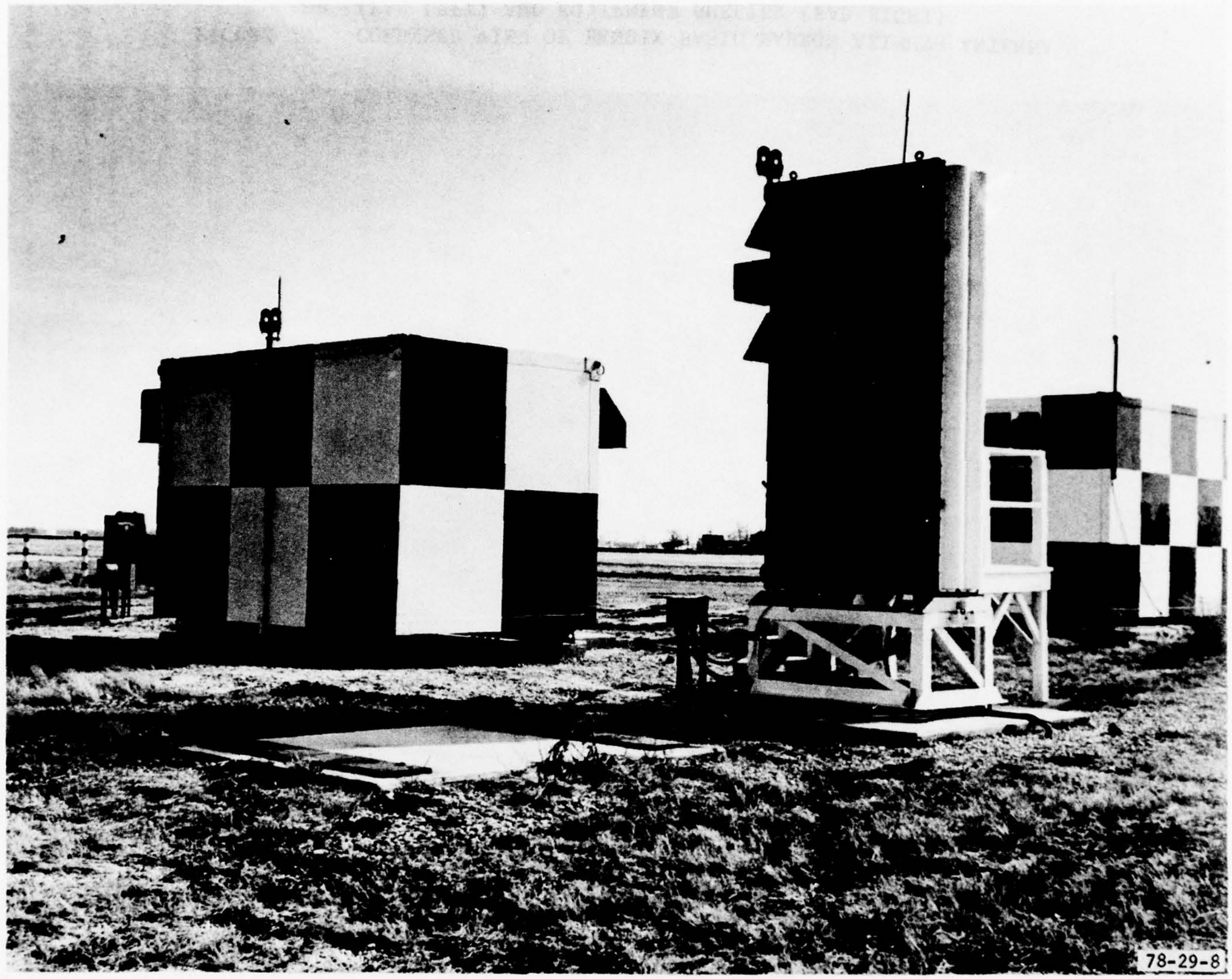


FIGURE 8. BENDIX BASIC NARROW ELEVATION ANTENNA AND EQUIPMENT SHELTER

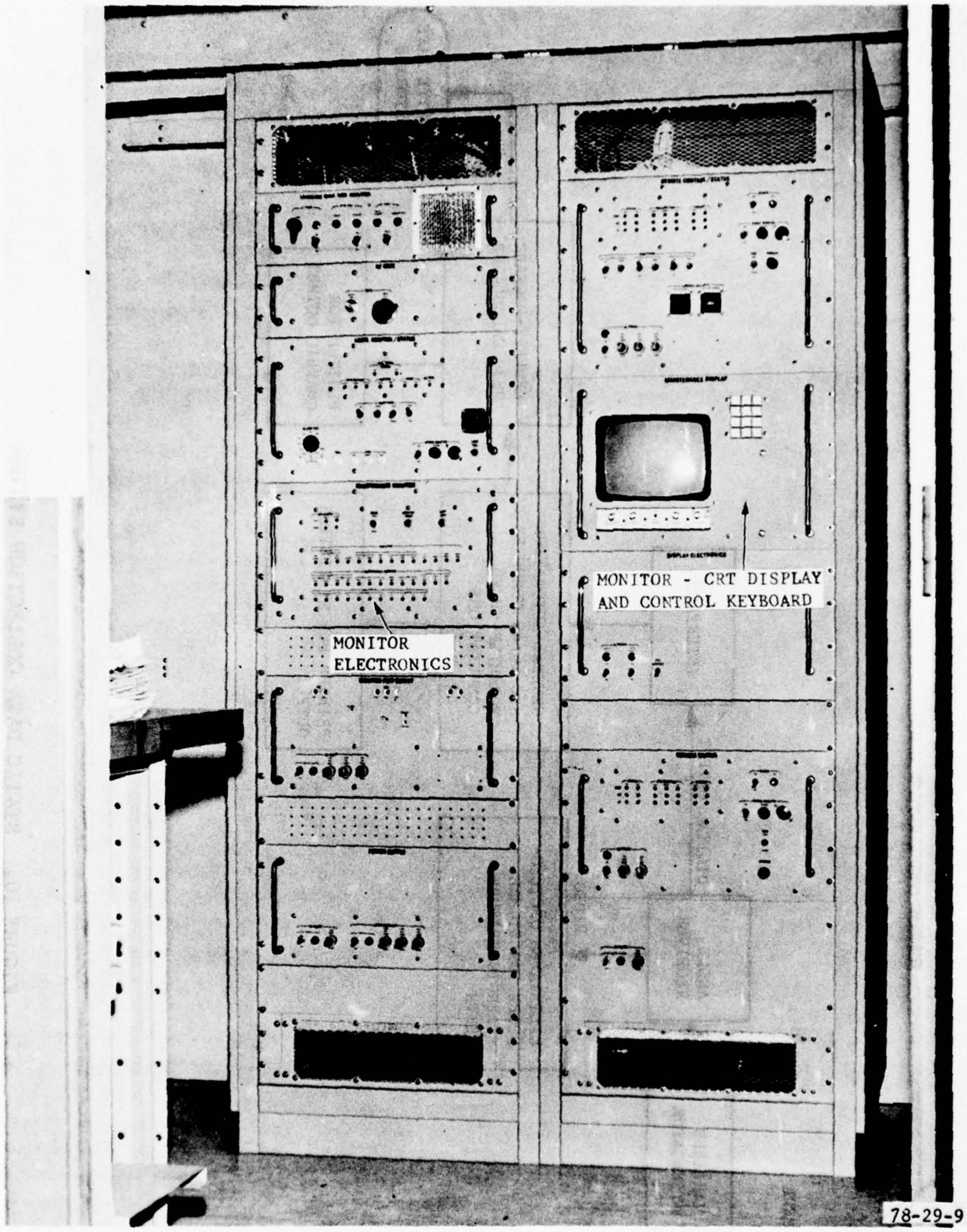


FIGURE 9. BENDIX BASIC NARROW AZIMUTH TRANSMITTER AND MONITOR ELECTRONICS

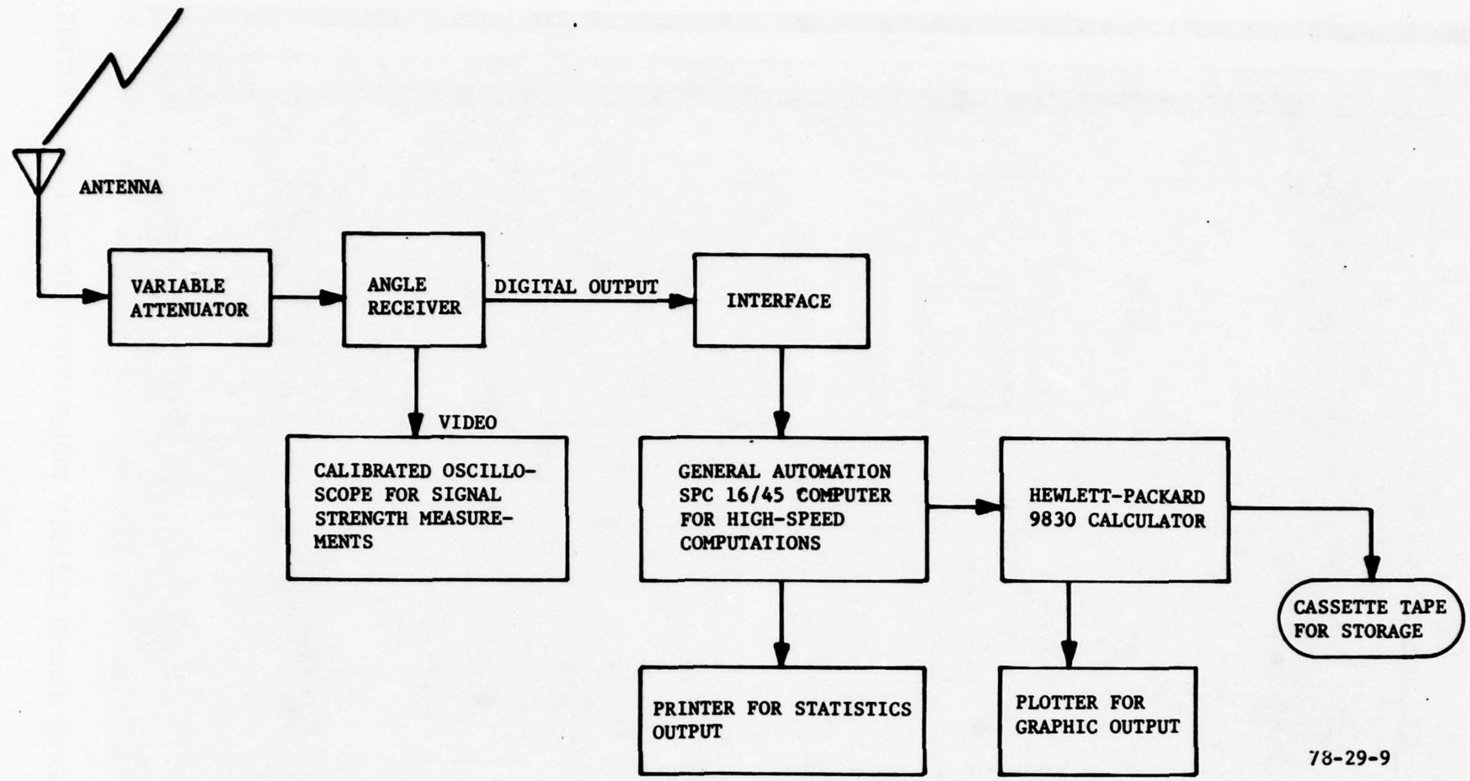
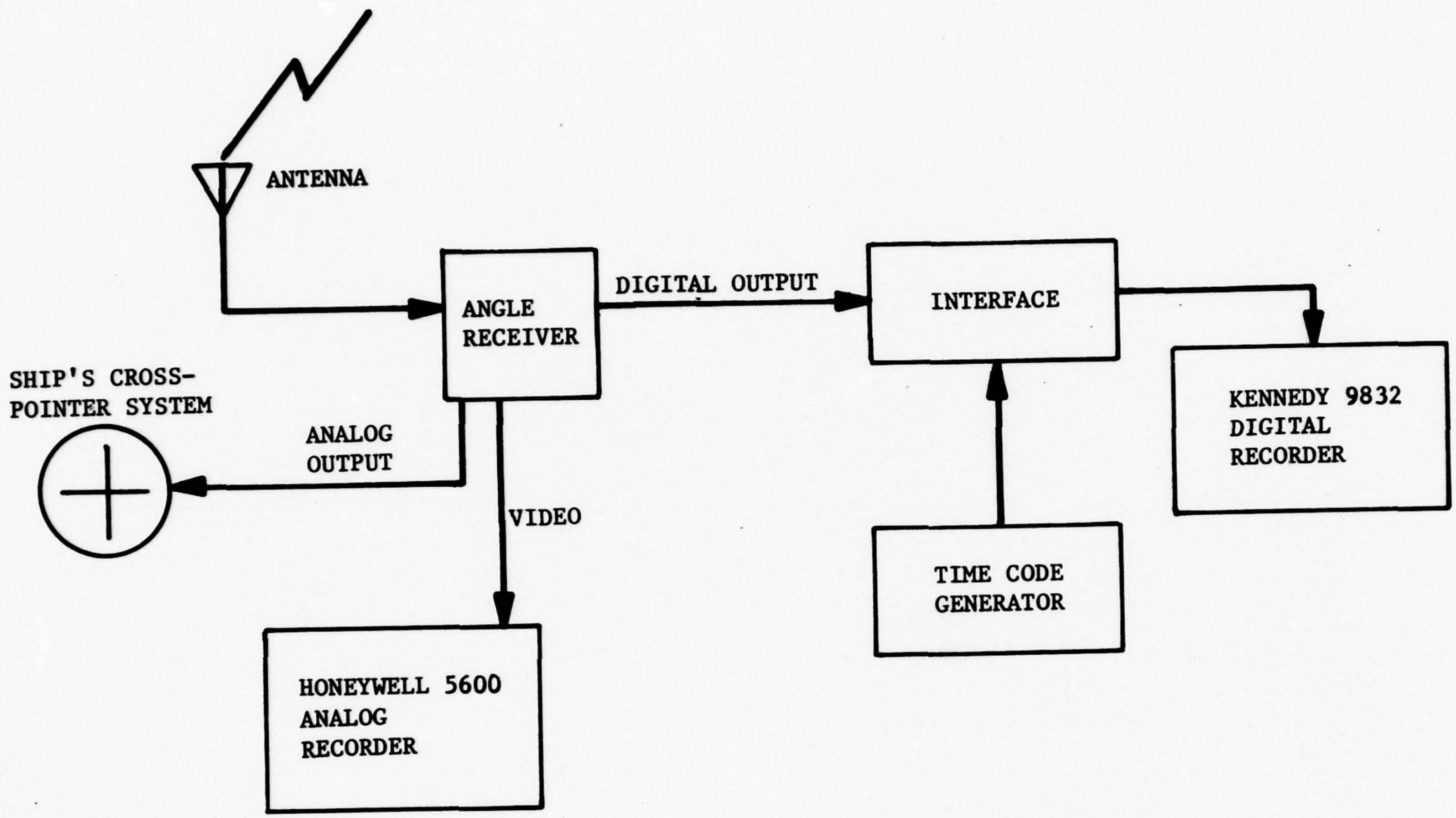


FIGURE 10. STATIC DATA COLLECTION SYSTEM

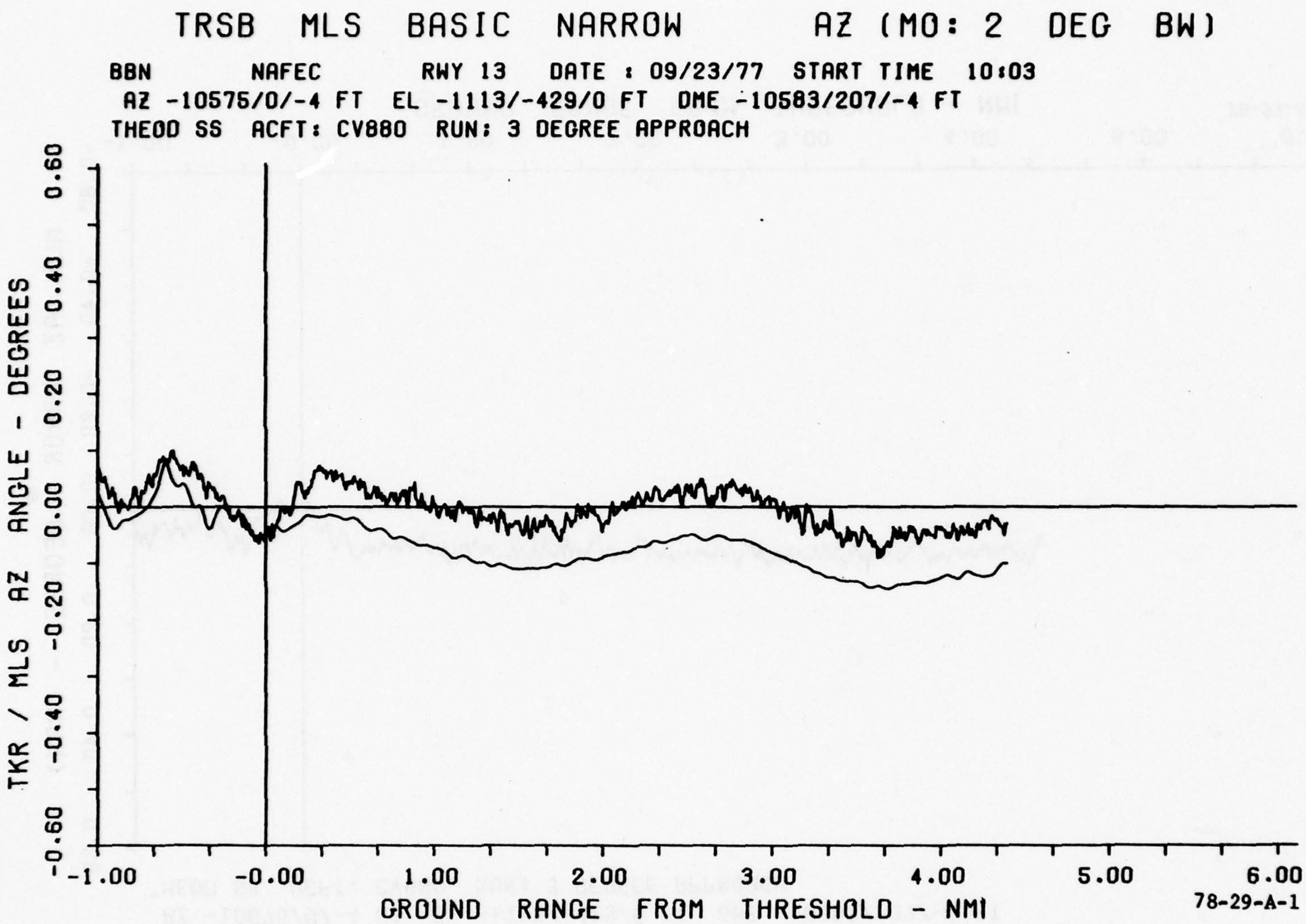


78-29-10

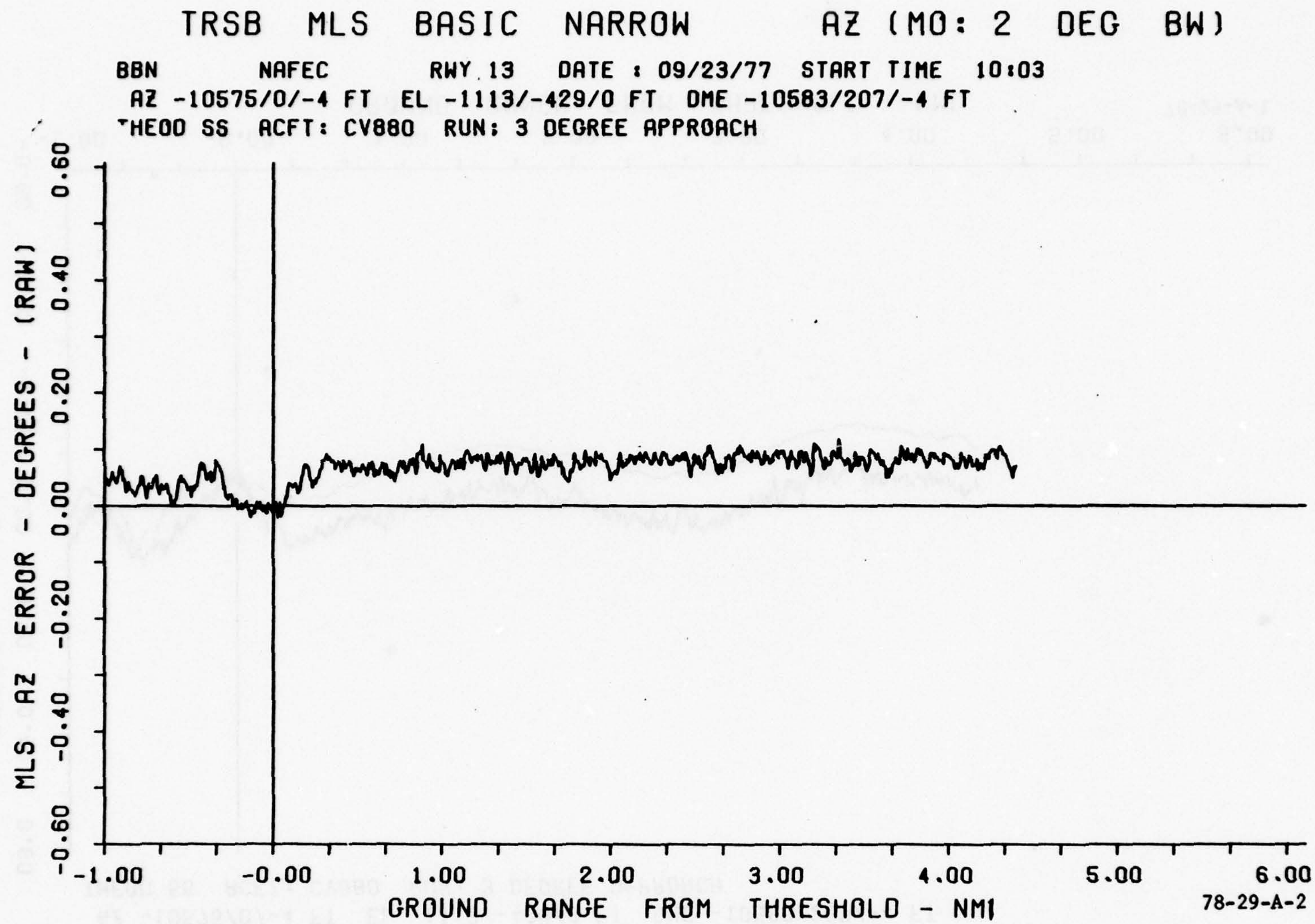
FIGURE 11. AIRBORNE DATA COLLECTION SYSTEM

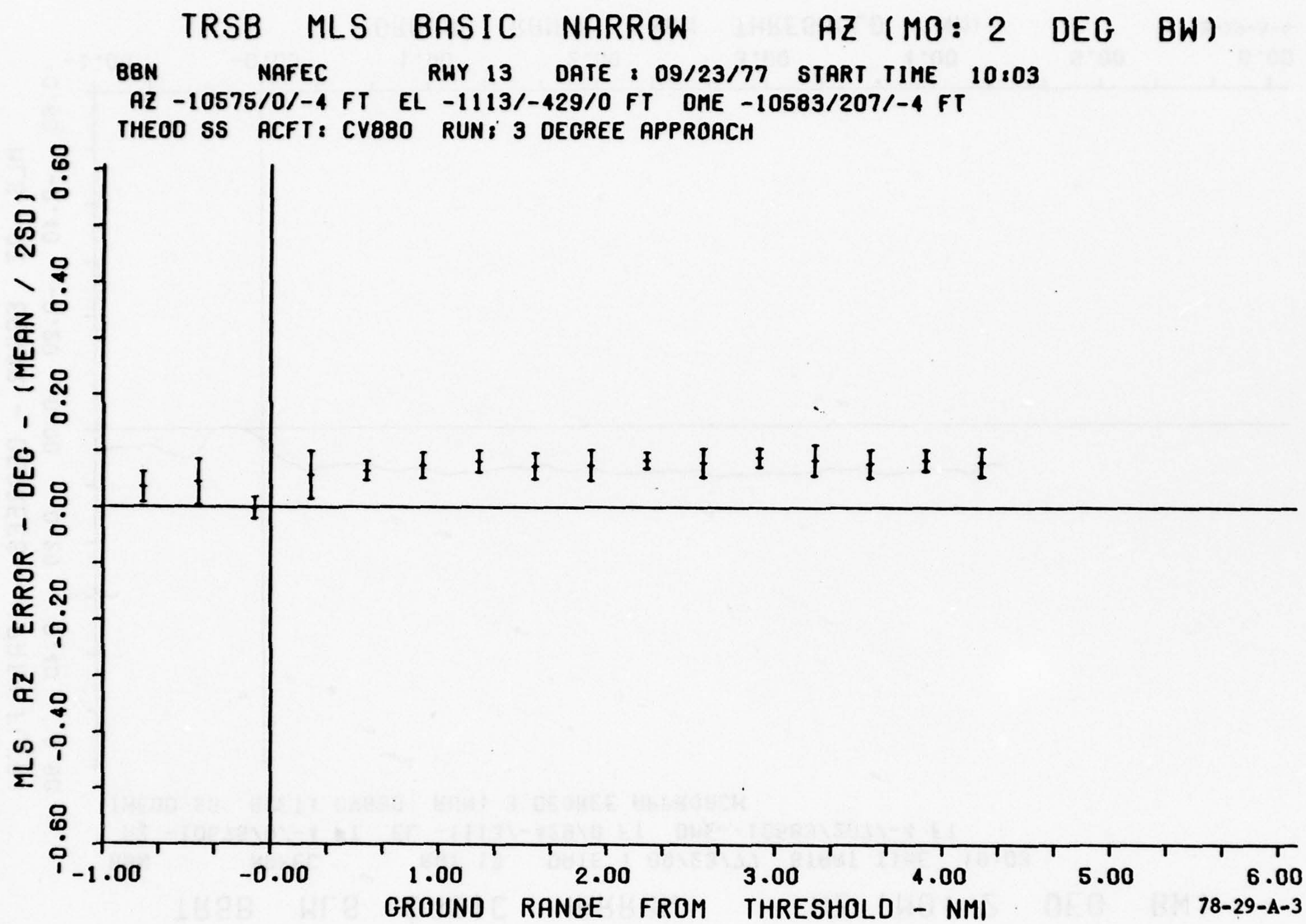
APPENDIX A

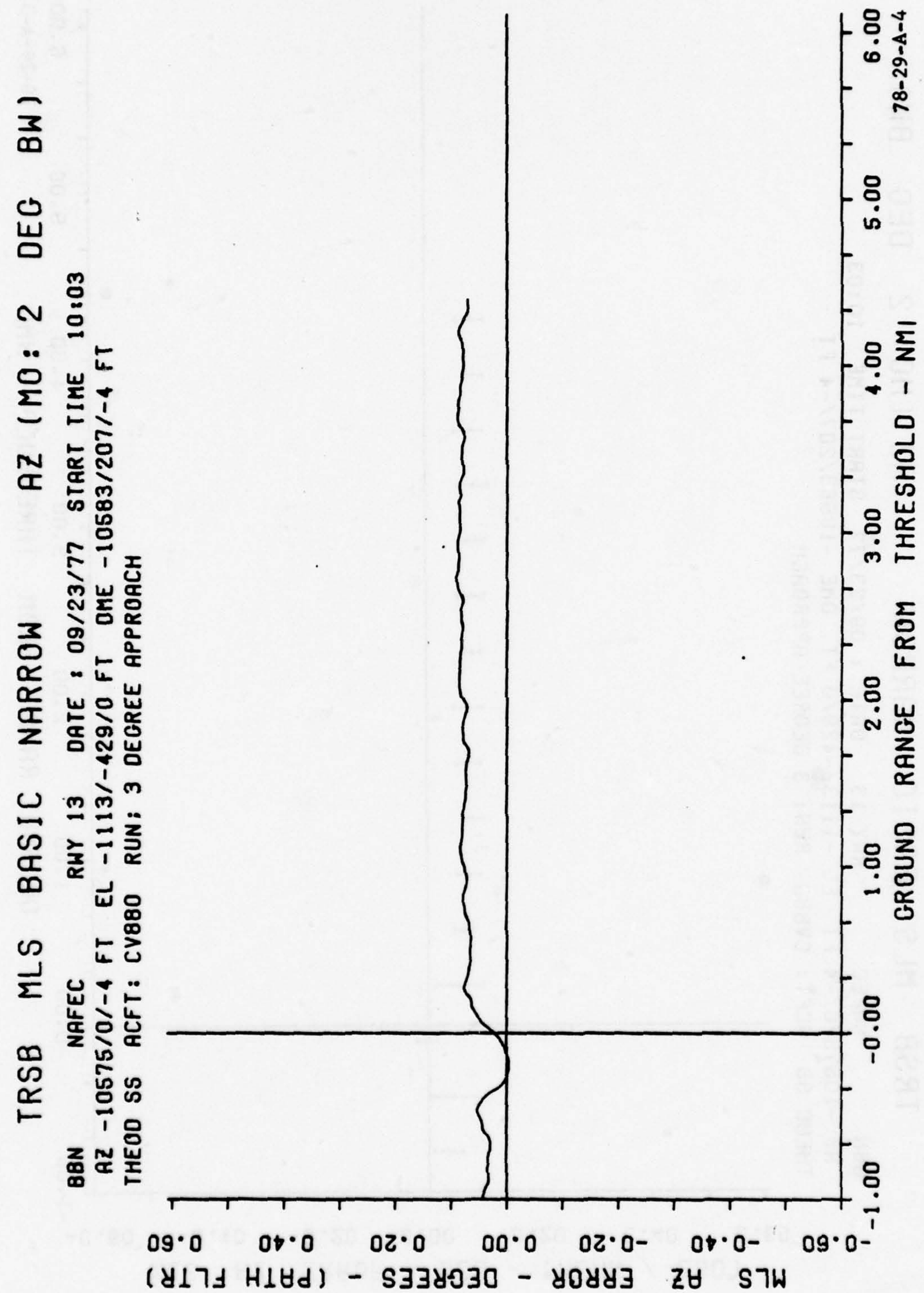
FLIGHT DATA

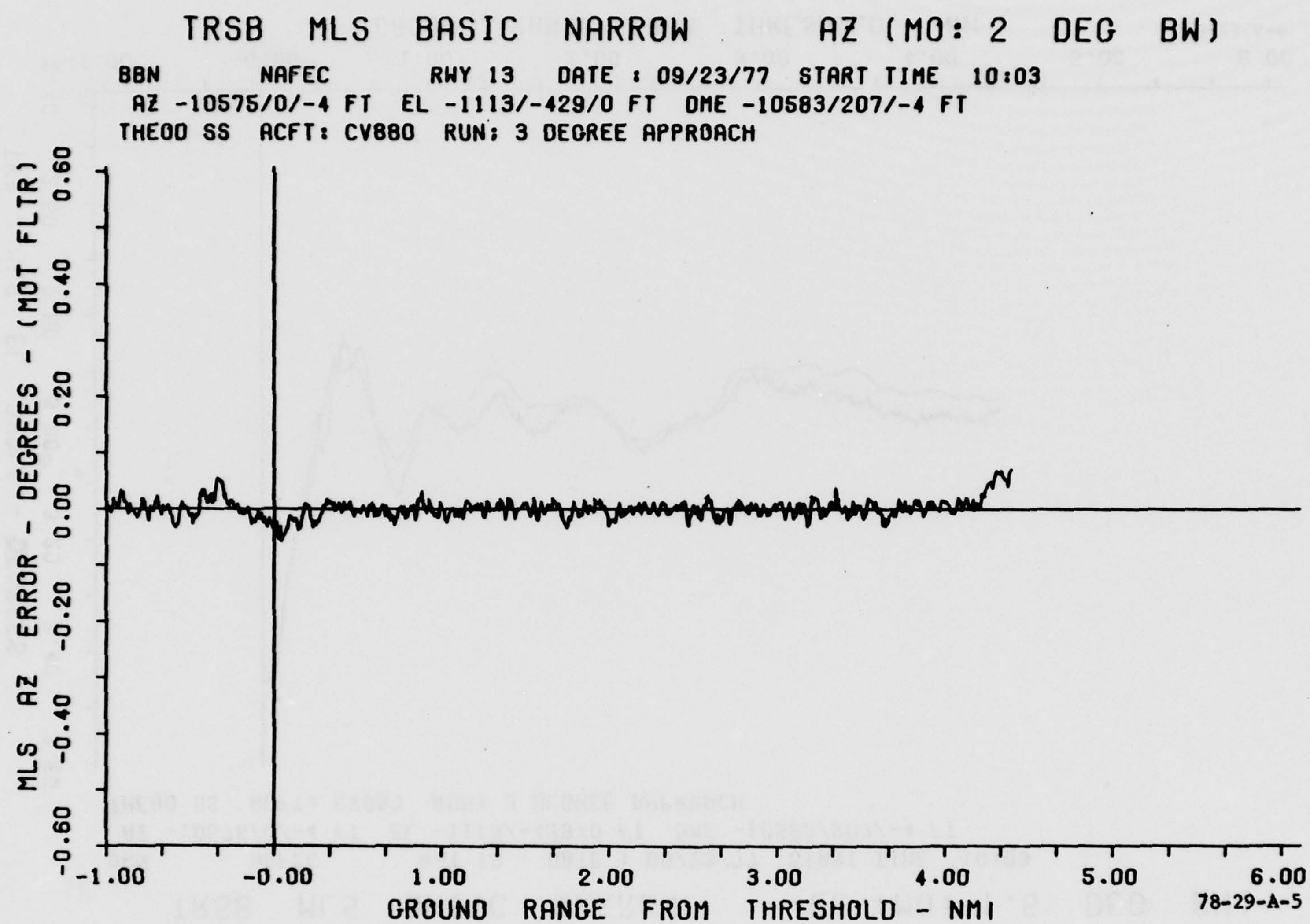

TRSB MLS BASIC NARROW AZ (MO: 2 DEG BW)
BBN NAFEC RWY 13 DATE : 09/23/77 START TIME 10:03
AZ -10575/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT
THEOD SS ACFT: CV880 RUN: 3 DEGREE APPROACH
TKR / MLS AZ ANGLE - DEGREES
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-1.00
-0.00
1.00
2.00
3.00
4.00
5.00
6.00
GROUND RANGE FROM THRESHOLD - NMI

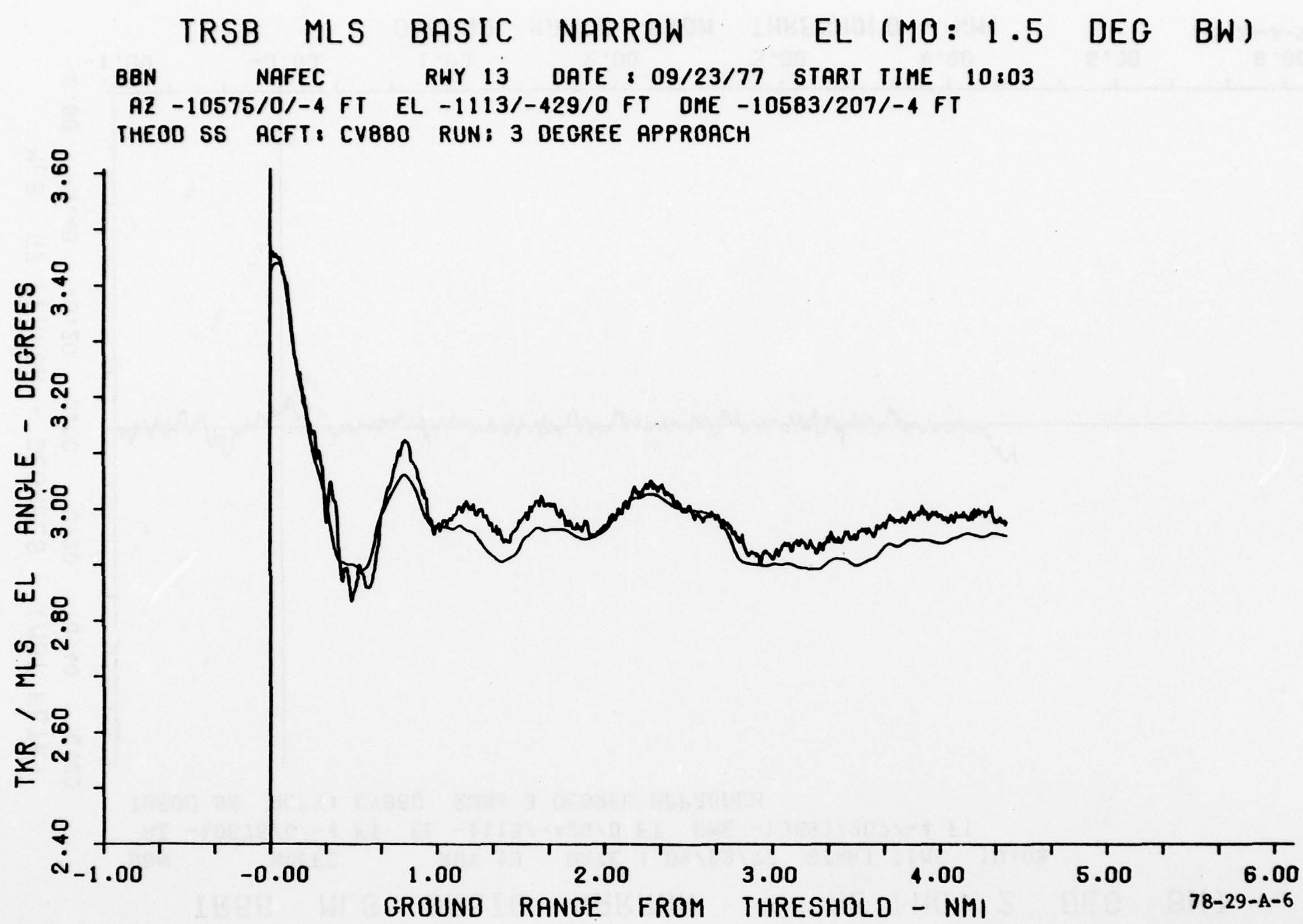
78-29-A-1


TRSB MLS BASIC NARROW AZ (MO: 2 DEG BW)
BBN NAFEC RWY 13 DATE : 09/23/77 START TIME 10:03
AZ -10575/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT
THEOD SS ACFT: CV880 RUN: 3 DEGREE APPROACH
MLS AZ ERROR - DEGREES - (RAW)
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-1.00
-0.00
1.00
2.00
3.00
4.00
5.00
6.00
GROUND RANGE FROM THRESHOLD - NMI
78-29-A-2


TRSB MLS BASIC NARROW AZ (MO: 2 DEG BW)
BBN NAFEC RWY 13 DATE : 09/23/77 START TIME 10:03
AZ -10575/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT
THEOD SS ACFT: CV880 RUN; 3 DEGREE APPROACH
MLS AZ ERROR - DEG - (MEAN / 2SD)
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-1.00
-0.00
1.00
2.00
3.00
4.00
5.00
6.00
GROUND RANGE FROM THRESHOLD - NMI
78-29-A-3

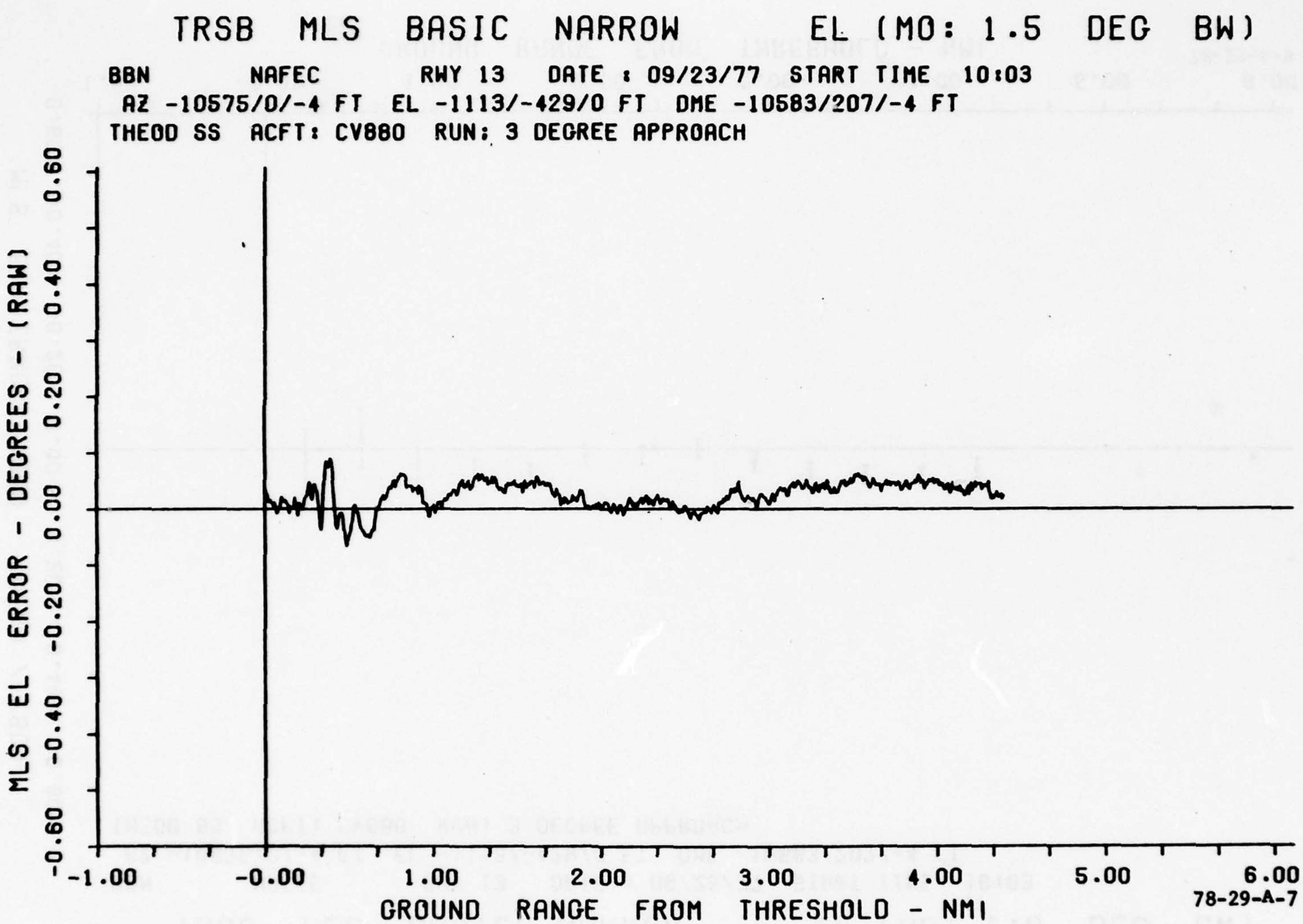

TRSB MLS BASIC NARROW AZ (MO: 2 DEG BW)
BBN NAFEC RWY 13 DATE : 09/23/77 START TIME 10:03
AZ -10575/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT
THEOD SS ACFT: CV880 RUN: 3 DEGREE APPROACH
MLS AZ ERROR - DEGREES - (PATH FLTR)
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-1.00
-0.00
1.00
2.00
3.00
4.00
5.00
6.00
GROUND RANGE FROM THRESHOLD - NMI
78-29-A-4


TRSB MLS BASIC NARROW AZ (MO: 2 DEG BW)
BBN NAFEC RWY 13 DATE : 09/23/77 START TIME 10:03
AZ -10575/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT
THEOD SS ACFT: CV880 RUN; 3 DEGREE APPROACH
MLS AZ ERROR - DEGREES - (MOT FLTR)
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-1.00
-0.00
1.00
2.00
3.00
4.00
5.00
6.00
GROUND RANGE FROM THRESHOLD - NMI
78-29-A-5



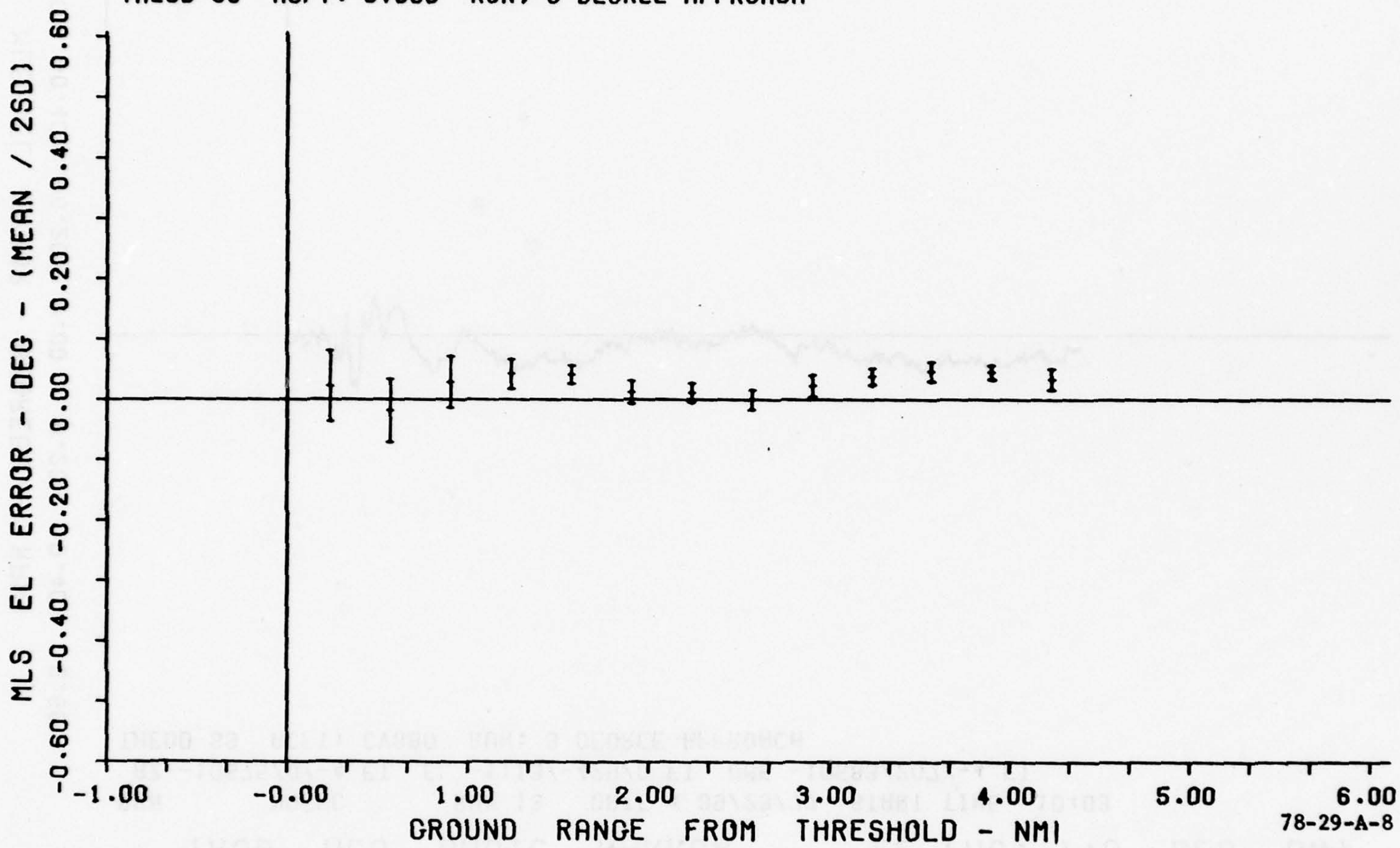
TRSB MLS BASIC NARROW EL (MO: 1.5 DEG BW)
BBN NAFEC RWY 13 DATE : 09/23/77 START TIME 10:03
AZ -10575/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT
THEOD SS ACFT: CV880 RUN: 3 DEGREE APPROACH
TKR / MLS EL ANGLE - DEGREES
3.60
3.40
3.20
3.00
2.80
2.60
2.40
-1.00
-0.00
1.00
2.00
3.00
4.00
5.00
6.00
GROUND RANGE FROM THRESHOLD - NMI

78-29-A-6

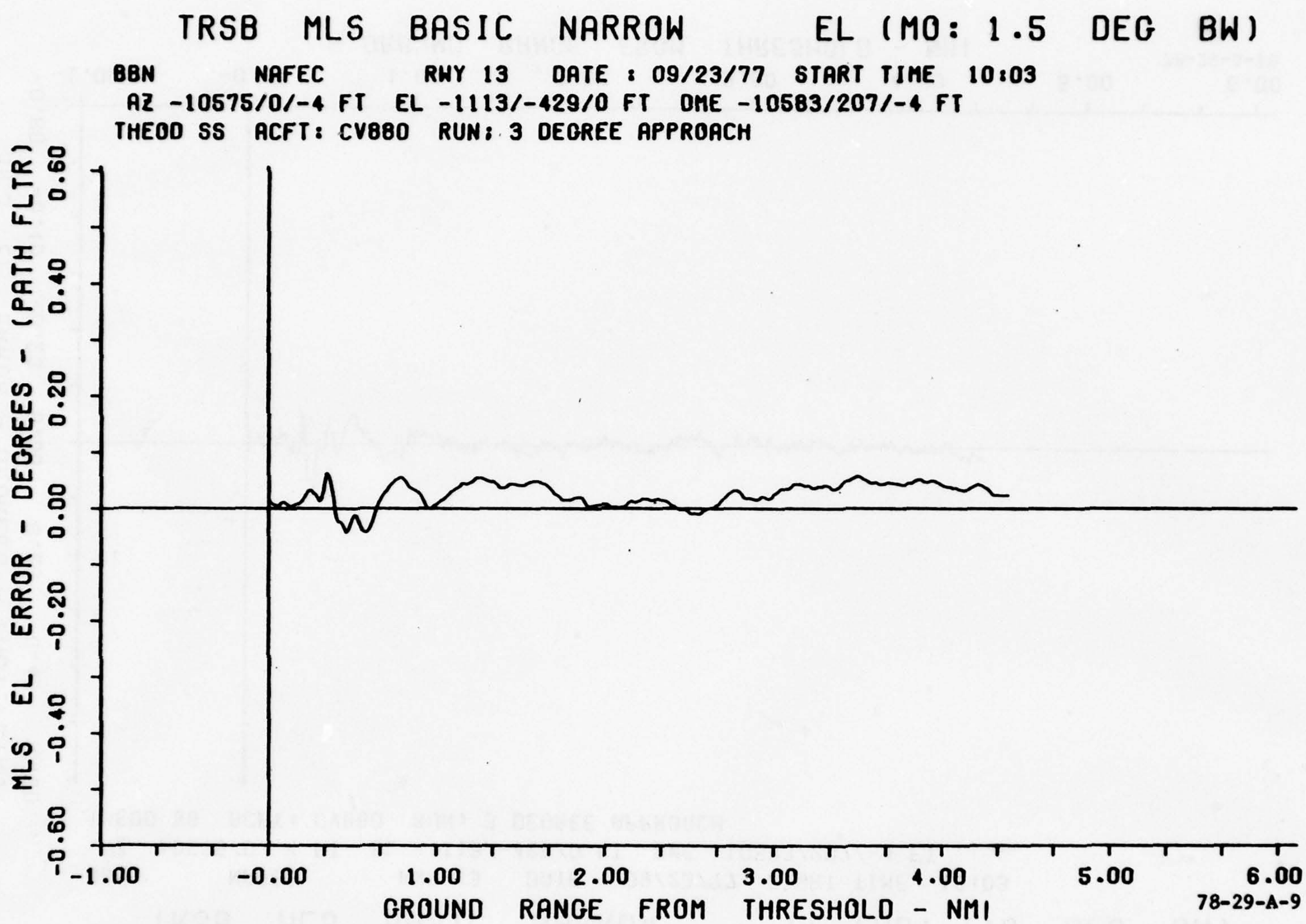

TRSB MLS BASIC NARROW EL (MO: 1.5 DEG BW)
BBN NAFEC RWY 13 DATE : 09/23/77 START TIME 10:03
AZ -10575/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT
THEOD SS ACFT: CV880 RUN: 3 DEGREE APPROACH
MLS EL ERROR - DEGREES - (RAW)
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-1.00
-0.00
1.00
2.00
3.00
4.00
5.00
6.00
GROUND RANGE FROM THRESHOLD - NMI
78-29-A-7

TRSB MLS BASIC NARROW EL (MO: 1.5 DEG BW)

BBN NAFEC RWY 13 DATE : 09/23/77 START TIME 10:03
AZ -10575/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT
THEOD SS ACFT: CV880 RUN; 3 DEGREE APPROACH

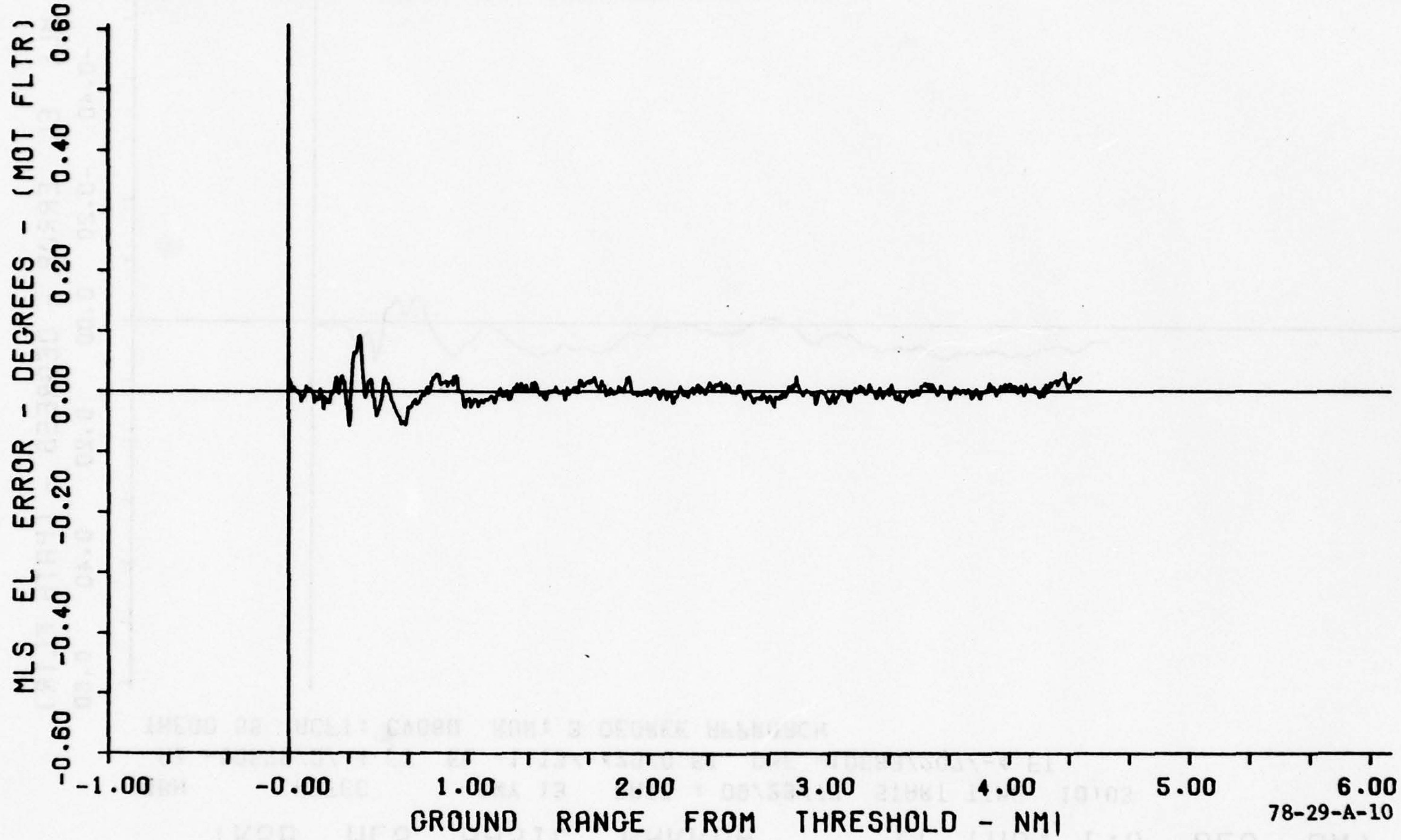


78-29-A-8


TRSB MLS BASIC NARROW EL (MO: 1.5 DEG BW)
BBN NAFEC RWY 13 DATE : 09/23/77 START TIME 10:03
AZ -10575/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT
THEOD SS ACFT: CV880 RUN; 3 DEGREE APPROACH
MLS EL ERROR - DEGREES - (PATH FLTR)
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-1.00
-0.00
1.00
2.00
3.00
4.00
5.00
6.00
GROUND RANGE FROM THRESHOLD - NMI
78-29-A-9

TRSB MLS BASIC NARROW EL (MO: 1.5 DEG BW)

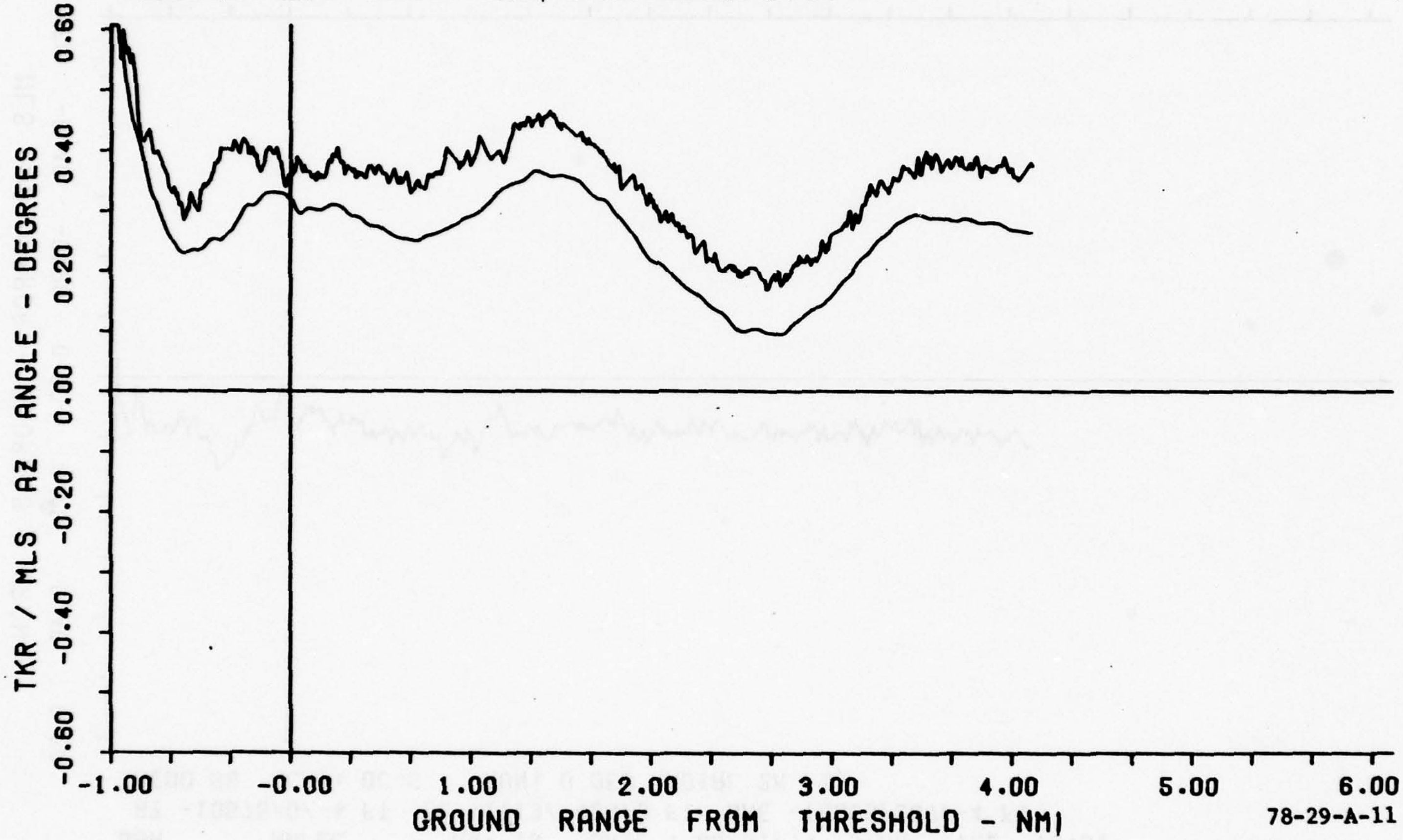
BBN NAFEC RWY 13 DATE : 09/23/77 START TIME 10:03
AZ -10575/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT
THEOD SS ACFT: CV880 RUN: 3 DEGREE APPROACH



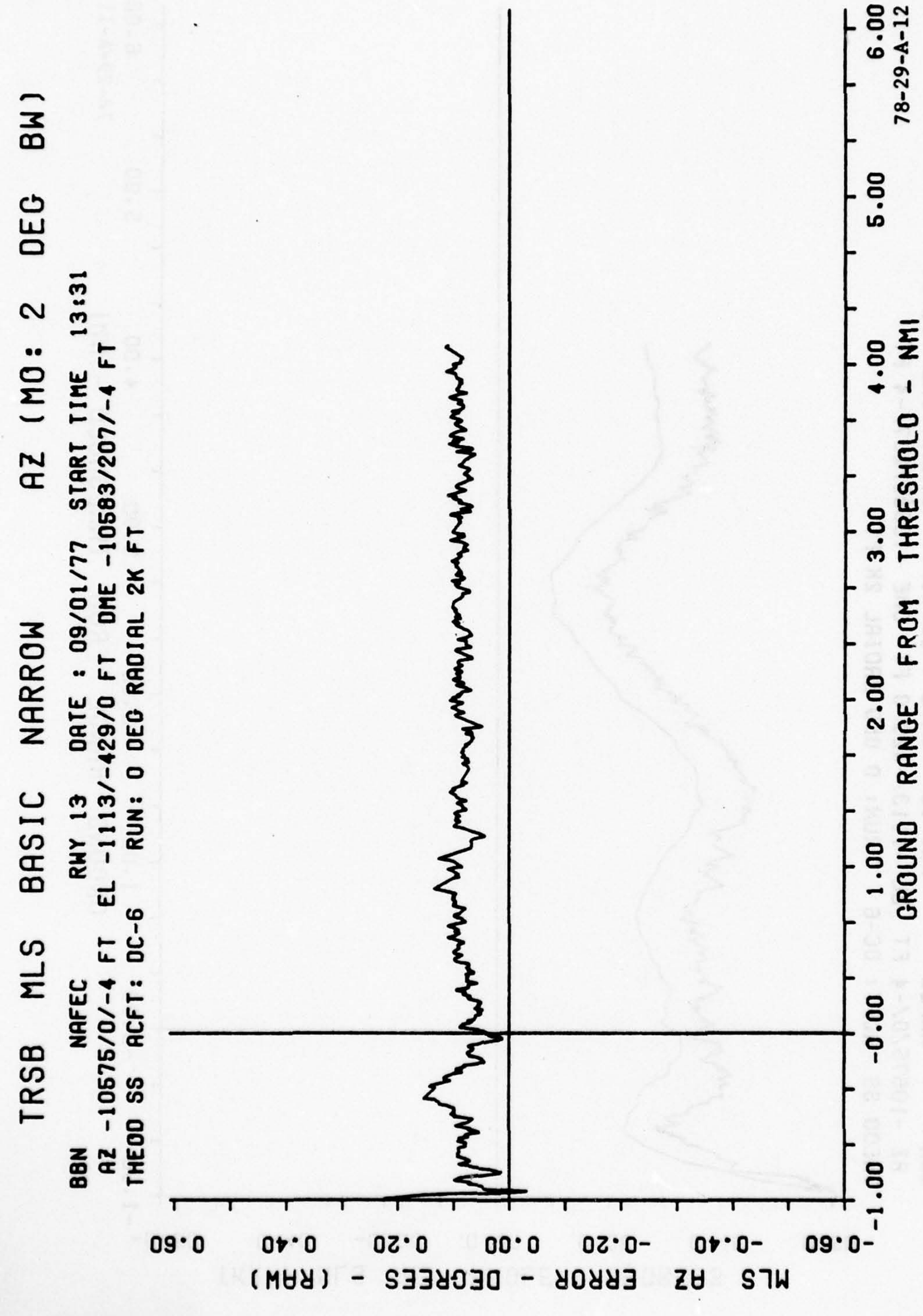
78-29-A-10

TRSB MLS BASIC NARROW AZ (MO: 2 DEG BW)

BBN NAFEC RWY 13 DATE : 09/01/77 START TIME 13:31
AZ -10575/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT
THEOD SS ACFT: DC-6 RUN: 0 DEG RADIAL 2K FT



78-29-A-11

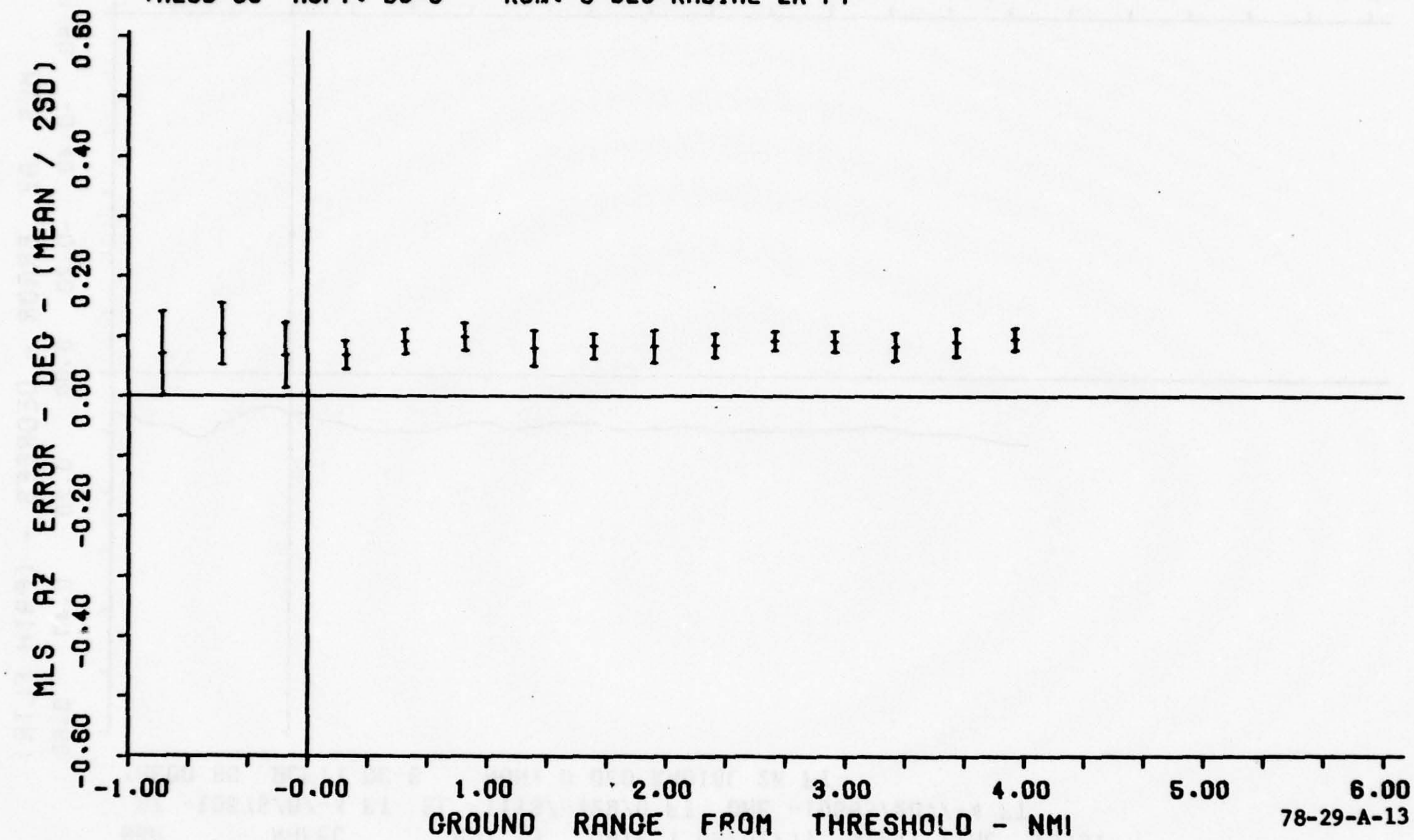

TRSB MLS BASIC NARROW AZ (MO: 2 DEG BW)
BBN NAFEC RWY 13 DATE : 09/01/77 START TIME 13:31
AZ -10575/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT
THEOD SS ACFT: DC-6 RUN: 0 DEG RADIAL 2K FT
MLS AZ ERROR - DEGREES - (RAW)
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-1.00
-0.00
1.00
2.00
3.00
4.00
5.00
6.00
GROUND RANGE FROM THRESHOLD - NMI
78-29-A-12

TRSB MLS BASIC NARROW AZ (MO: 2 DEG BW)

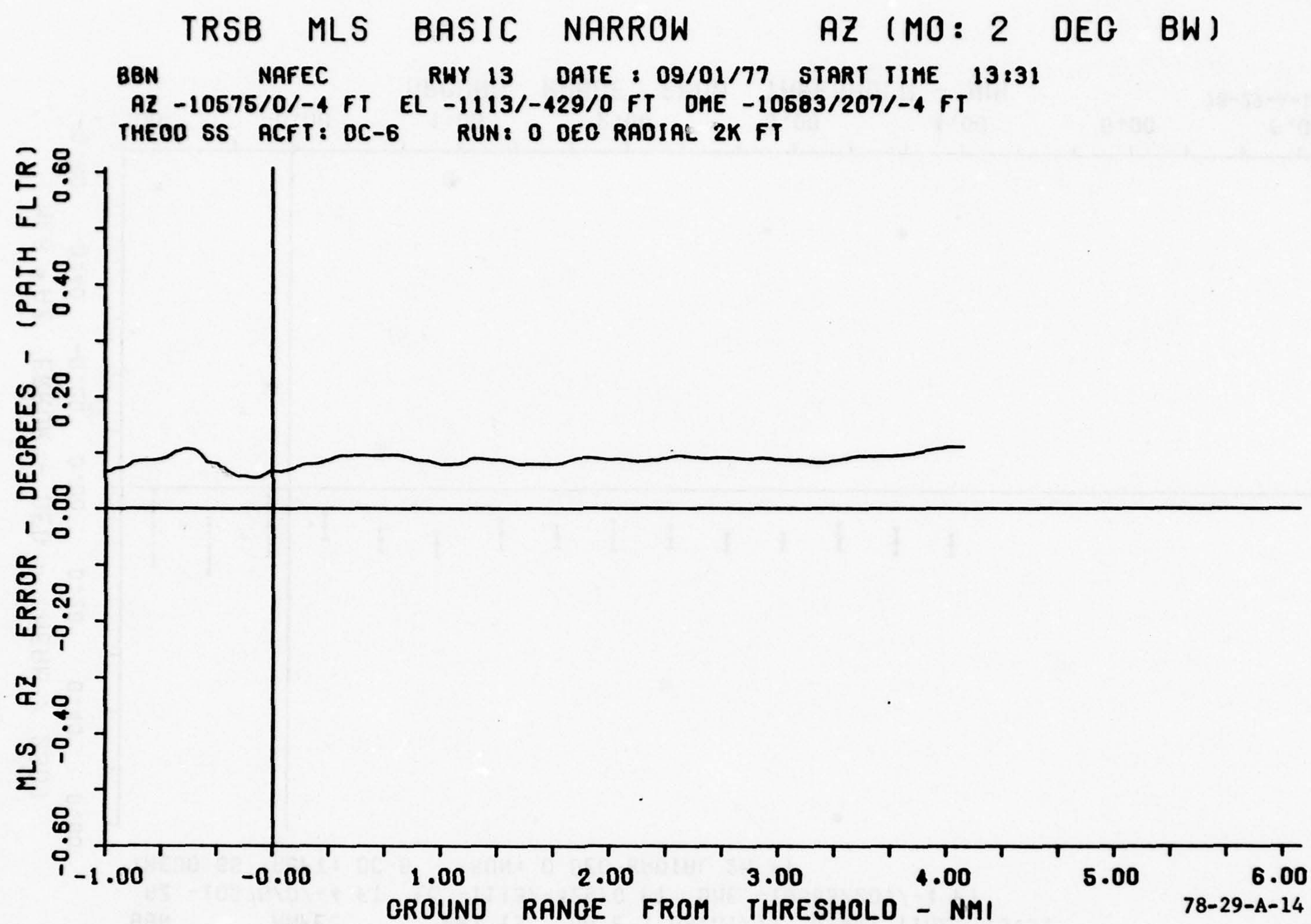
BBN NAFEC RWY 13 DATE : 09/01/77 START TIME 13:31

AZ -10575/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT

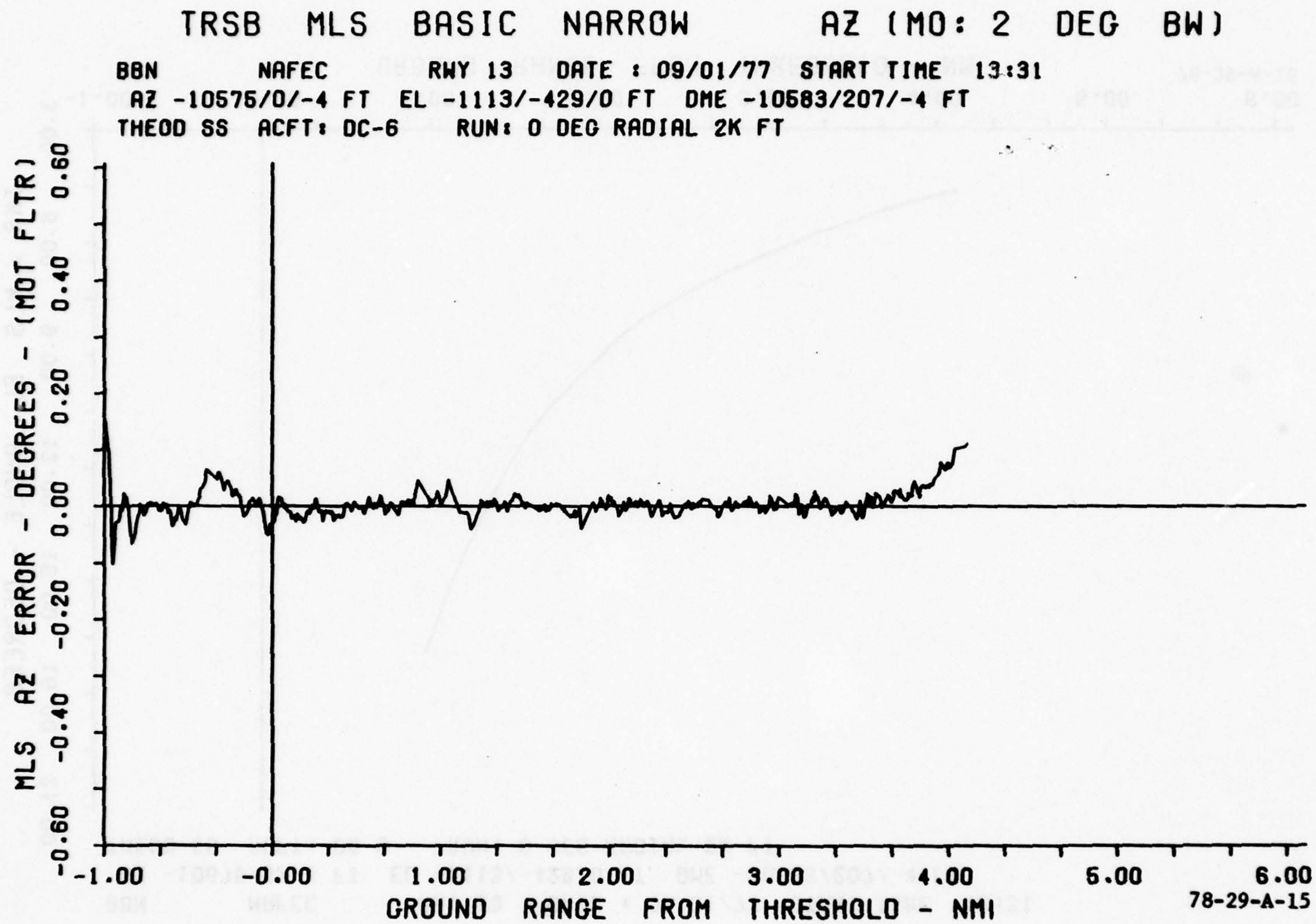
THEOD SS ACFT: DC-6 RUN: 0 DEG RADIAL 2K FT



78-29-A-13


TRSB MLS BASIC NARROW AZ (MO: 2 DEG BW)
BBN NAFEC RWY 13 DATE : 09/01/77 START TIME 13:31
AZ -10575/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT
THEOD SS ACFT: DC-6 RUN: 0 DEG RADIAL 2K FT
MLS AZ ERROR - DEGREES - (PATH FLTR)
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-1.00
-0.00
1.00
2.00
3.00
4.00
5.00
6.00
GROUND RANGE FROM THRESHOLD - NMI

78-29-A-14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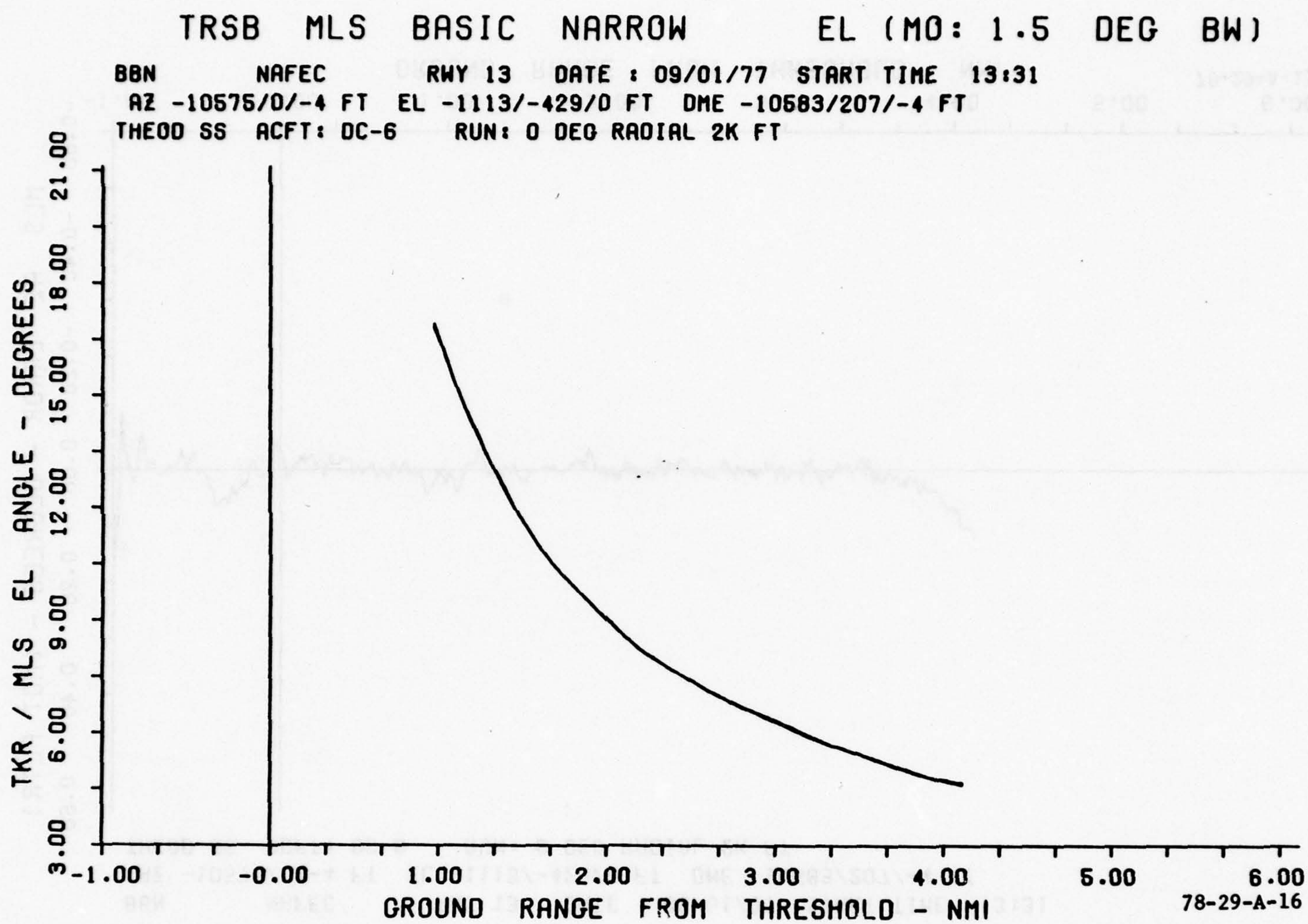
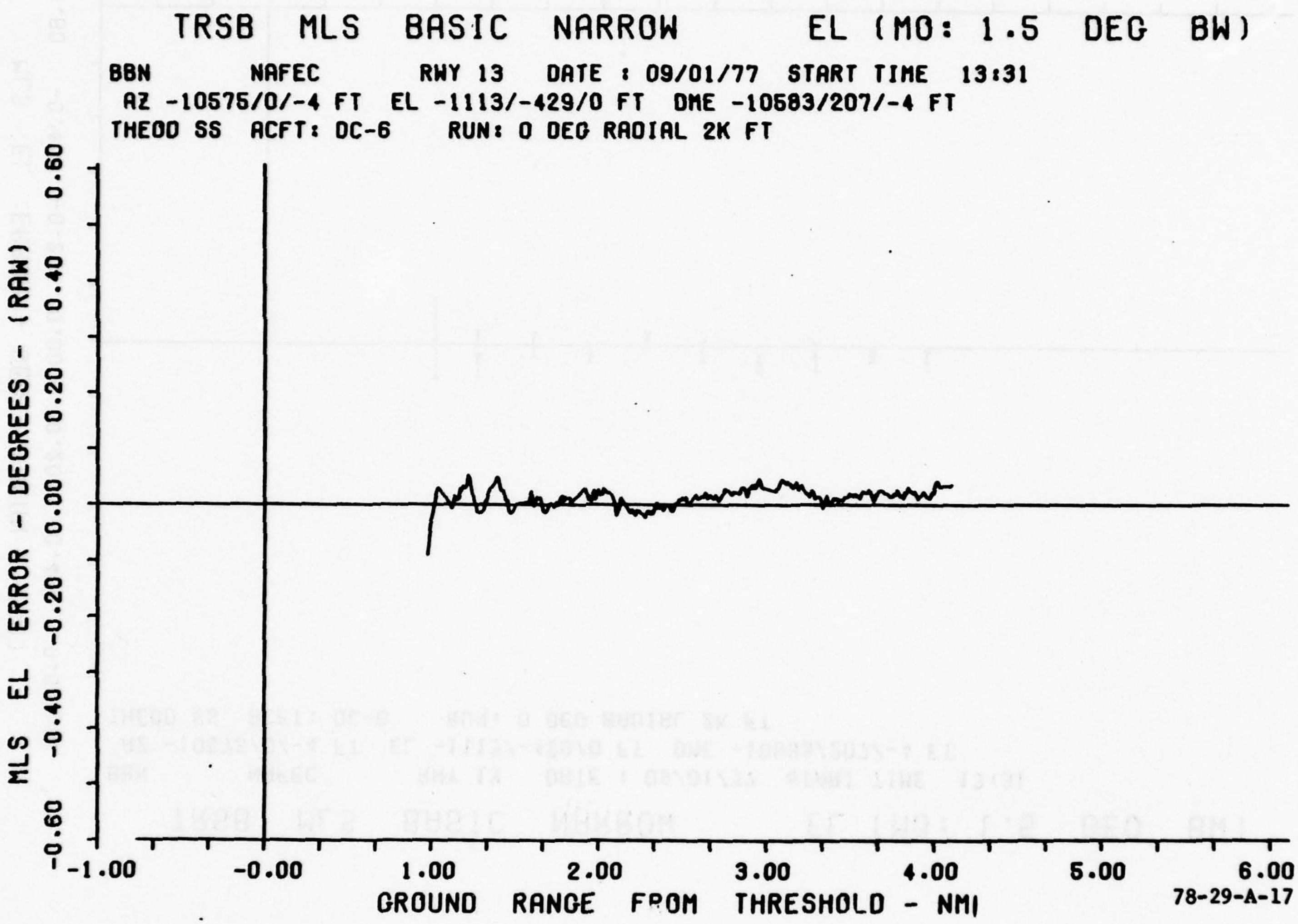
BBN NAFEC RWY 13 DATE : 09/01/77 START TIME 13:31
AZ -10576/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT
THEOD SS ACFT: DC-6 RUN: 0 DEG RADIAL 2K FT
MLS AZ ERROR - DEGREES - (MOT FLTR)
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-1.00
-0.00
1.00
2.00
3.00
4.00
5.00
6.00
GROUND RANGE FROM THRESHOLD - NMI
78-29-A-15

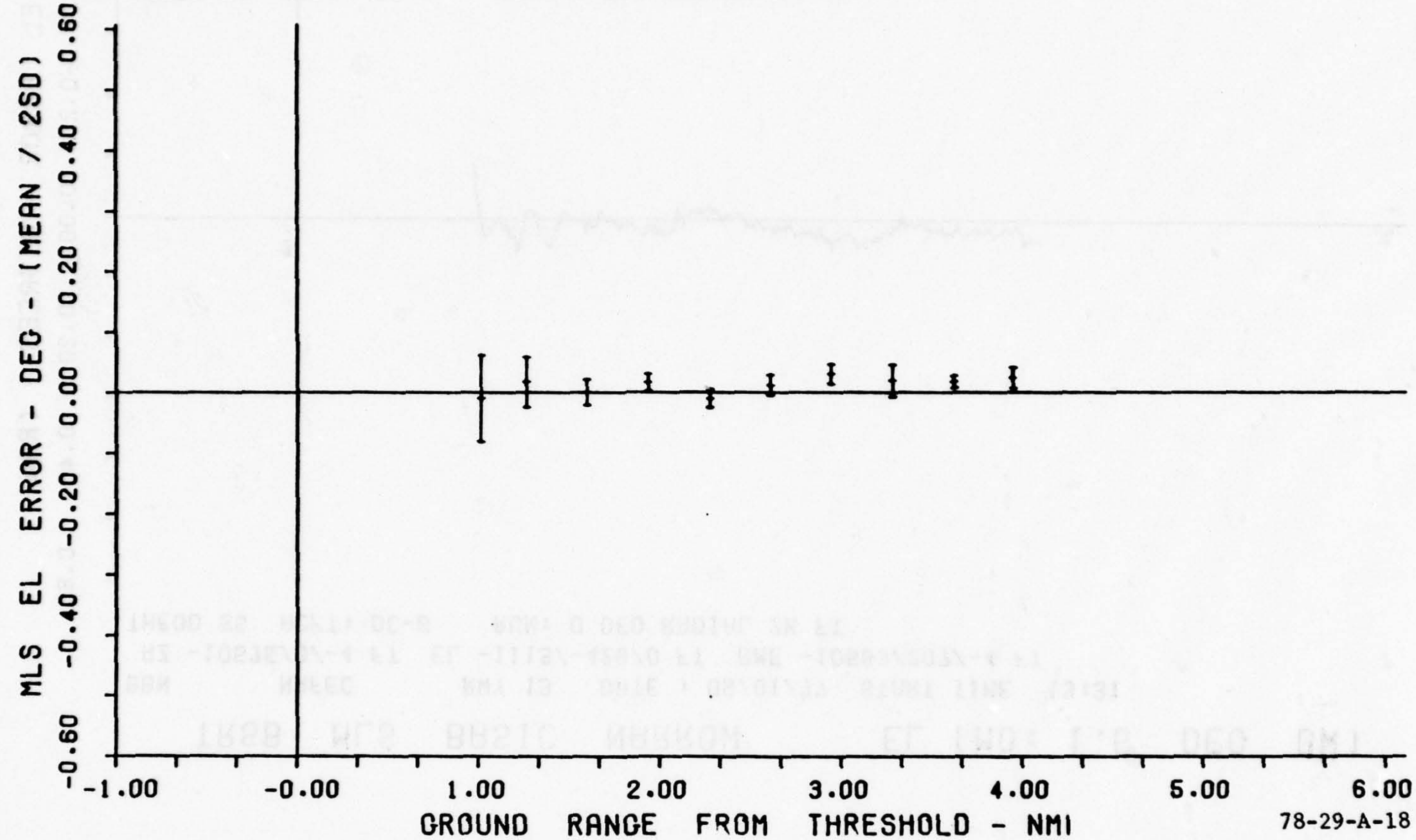

TRSB MLS BASIC NARROW EL (MO: 1.5 DEG BW)
BBN NAFEC RWY 13 DATE : 09/01/77 START TIME 13:31
AZ -10575/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT
THEOD SS ACFT: DC-6 RUN: 0 DEG RADIAL 2K FT
TKR / MLS EL ANGLE - DEGREES
3.00
6.00
9.00
12.00
15.00
18.00
21.00
-1.00
-0.00
1.00
2.00
3.00
4.00
5.00
6.00
GROUND RANGE FROM THRESHOLD - NMI
78-29-A-16



TRSB MLS BASIC NARROW EL (MO: 1.5 DEG BW)
BBN NAFEC RWY 13 DATE : 09/01/77 START TIME 13:31
AZ -10575/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT
THEOD SS ACFT: DC-6 RUN: 0 DEG RADIAL 2K FT
MLS EL ERROR - DEGREES - (RAW)
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-1.00
-0.00
1.00
2.00
3.00
4.00
5.00
6.00
GROUND RANGE FROM THRESHOLD - NMI
78-29-A-17

TRSB MLS BASIC NARROW EL (MO: 1.5 DEG BW)

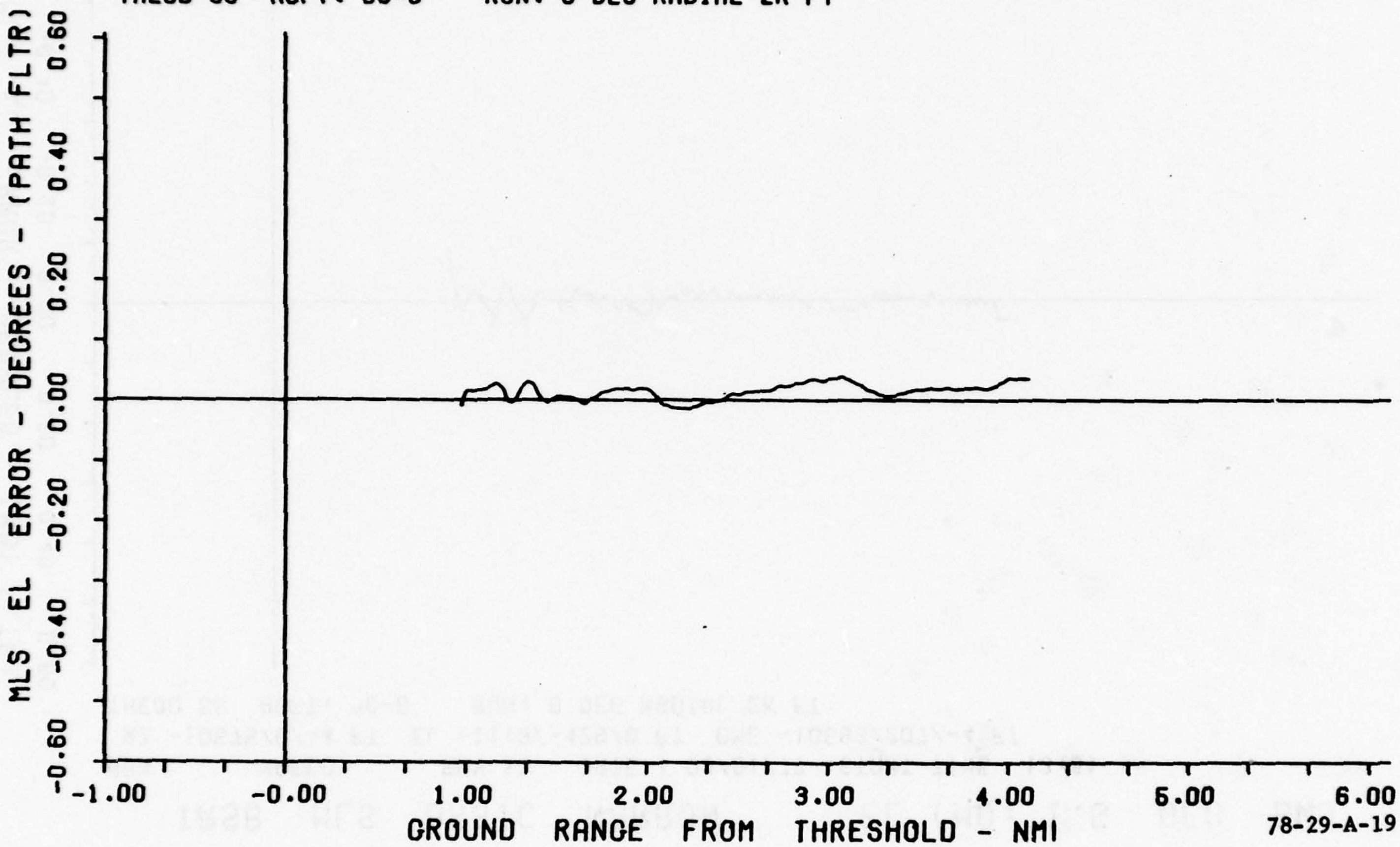
BBN NAFEC RWY 13 DATE : 09/01/77 START TIME 13:31
AZ -10575/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT
THEOD SS ACFT: DC-6 RUN: 0 DEG RADIAL 2K FT



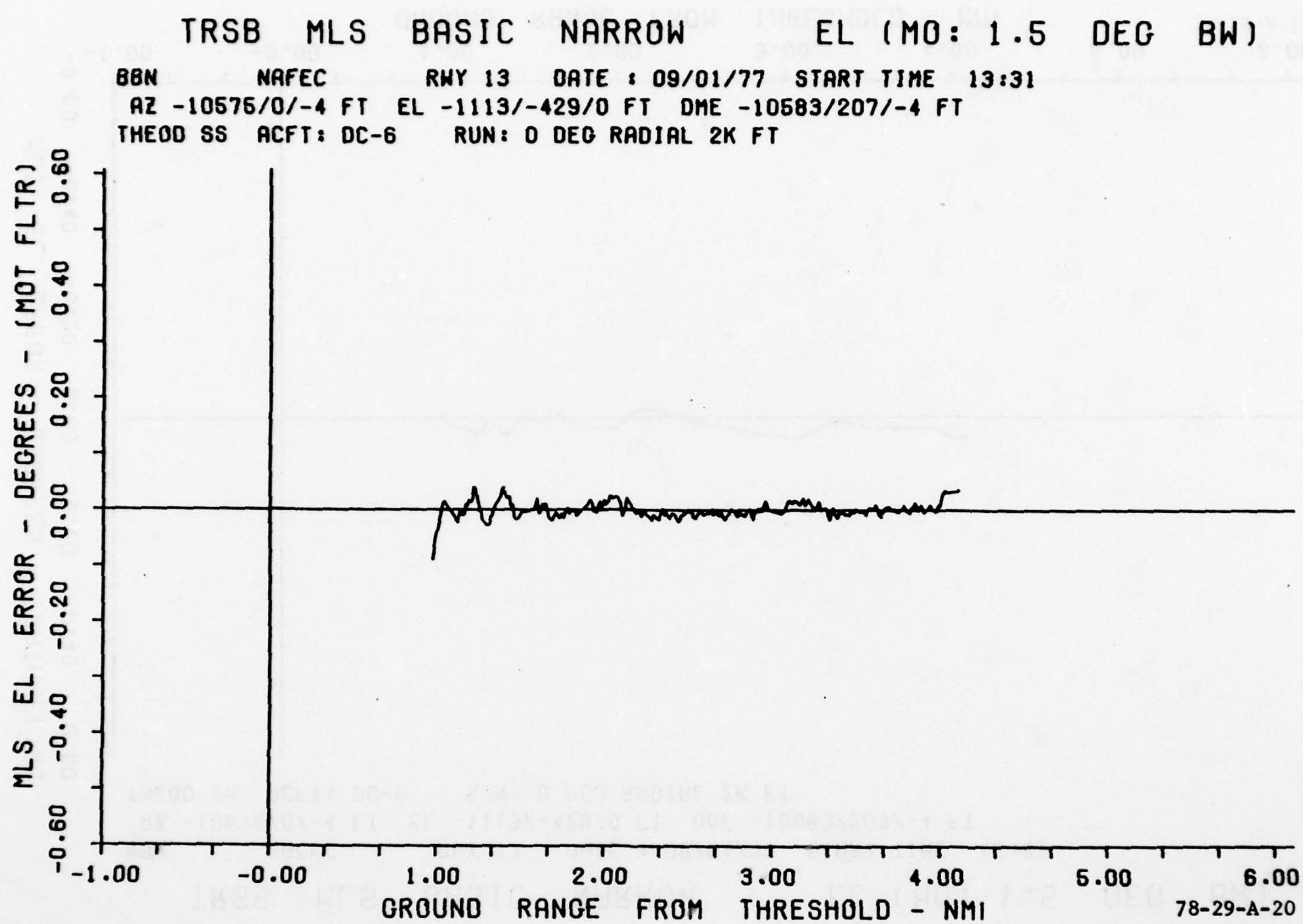
78-29-A-18

TRSB MLS BASIC NARROW EL (MO: 1.5 DEG BW)

BBN NAFEC RWY 13 DATE : 09/01/77 START TIME 13:31
AZ -10575/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT
THEOD SS ACFT: DC-6 RUN: 0 DEG RADIAL 2K FT

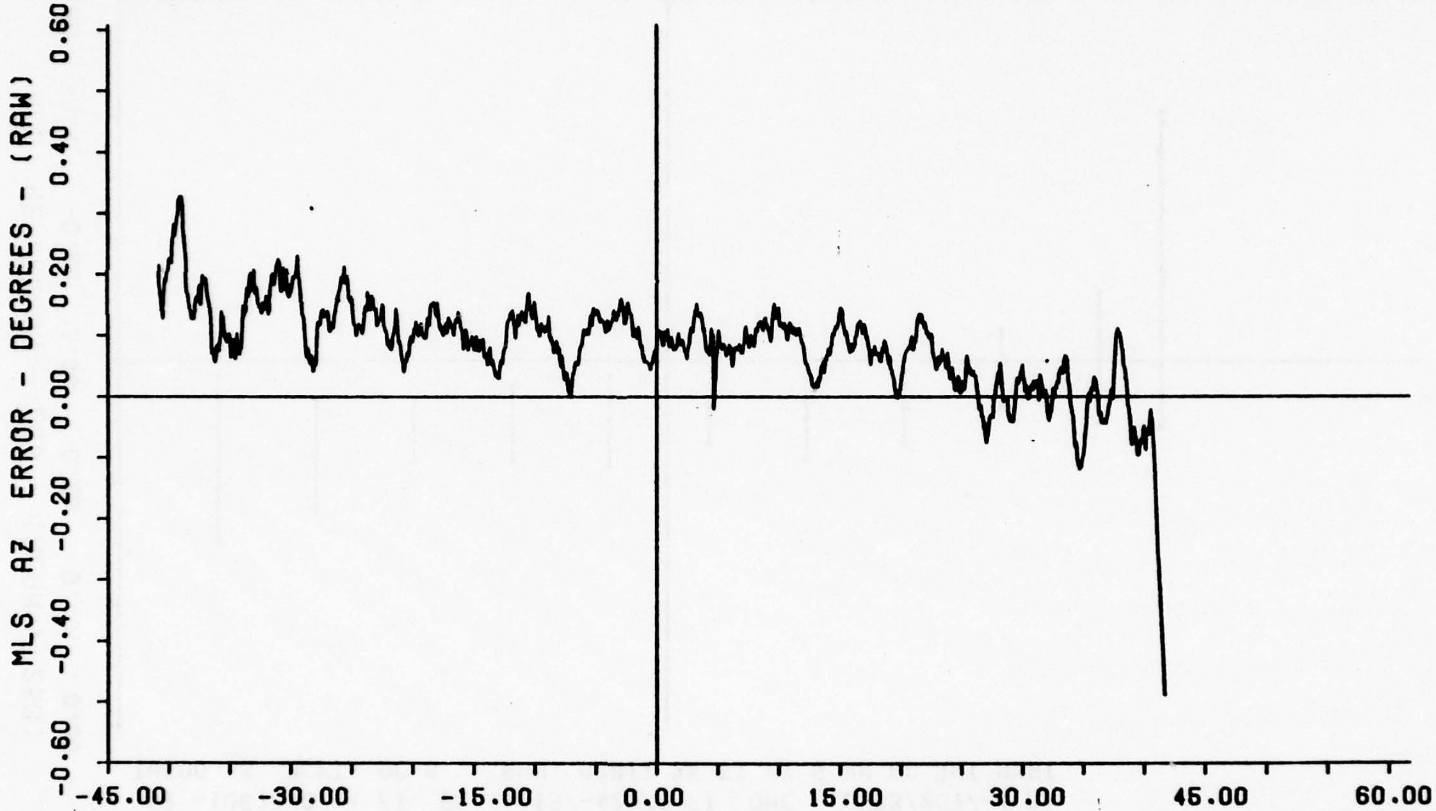


78-29-A-19

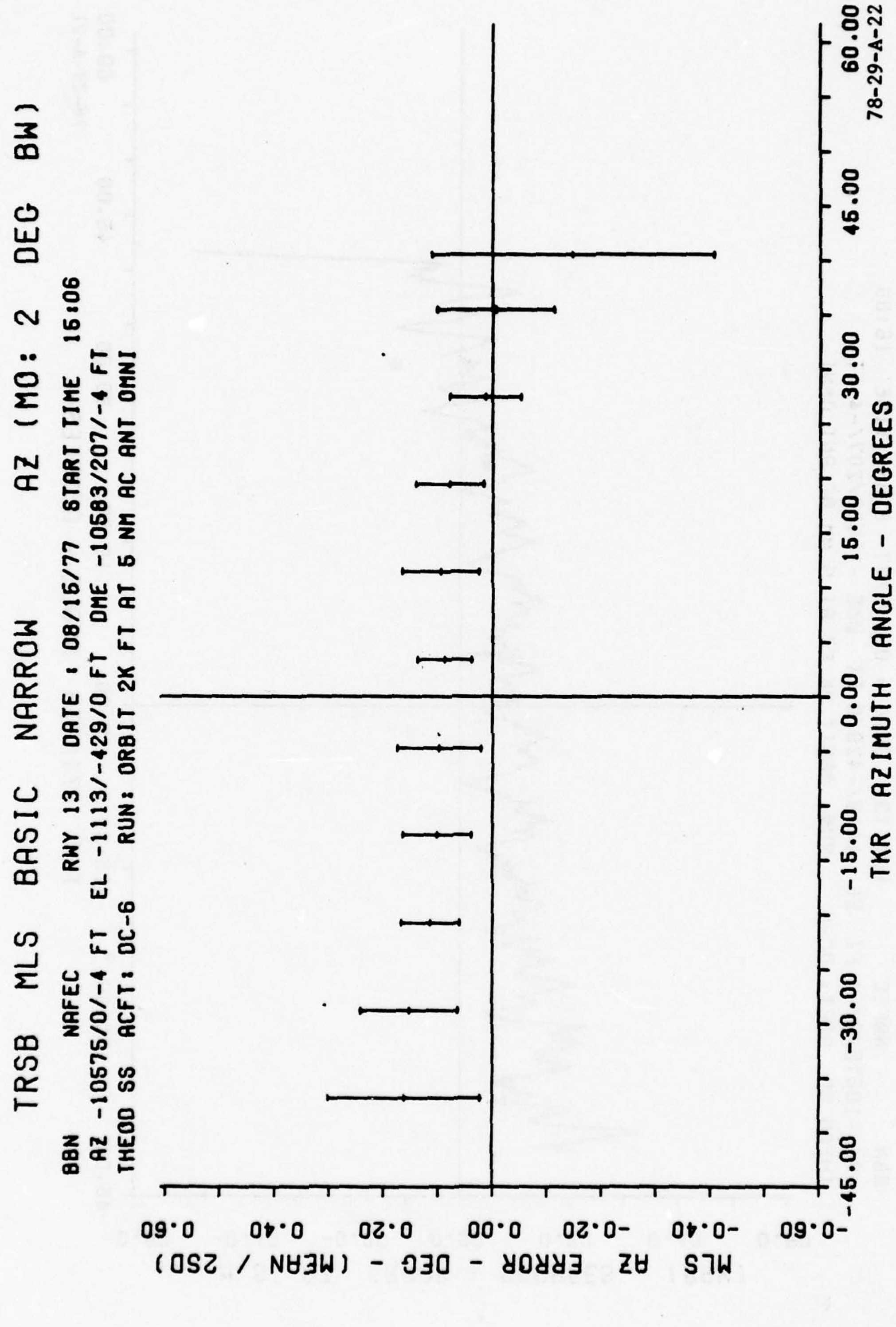

TRSB MLS BASIC NARROW EL (MO: 1.5 DEG BW)
BBN NAFEC RWY 13 DATE : 09/01/77 START TIME 13:31
AZ -10576/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT
THEOD SS ACFT: DC-6 RUN: 0 DEG RADIAL 2K FT
MLS EL ERROR - DEGREES - (MOT FLTR)
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-1.00
-0.00
1.00
2.00
3.00
4.00
5.00
6.00
GROUND RANGE FROM THRESHOLD - NMI
78-29-A-20

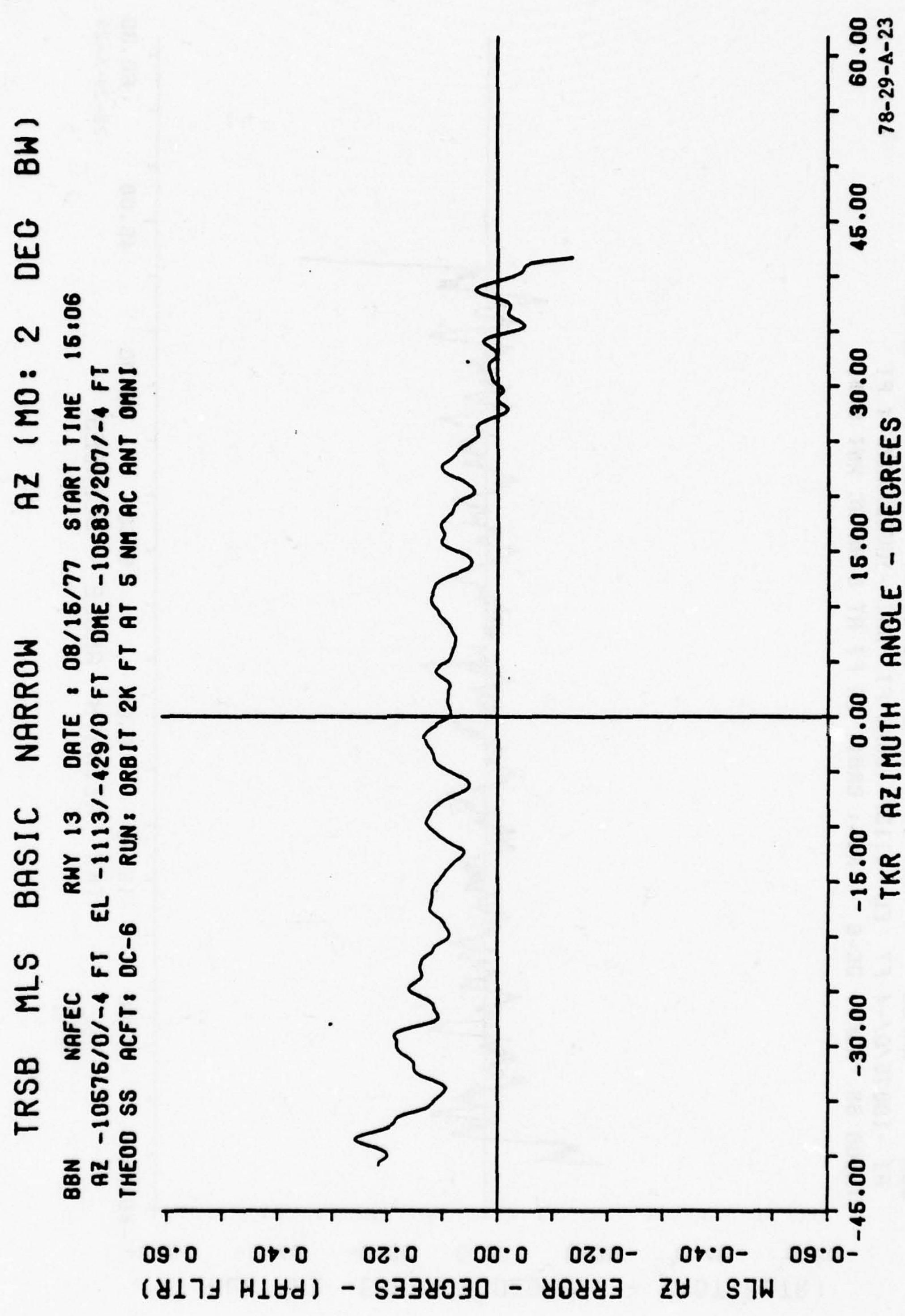
TRSB MLS BASIC NARROW AZ (MO: 2 DEG BW)

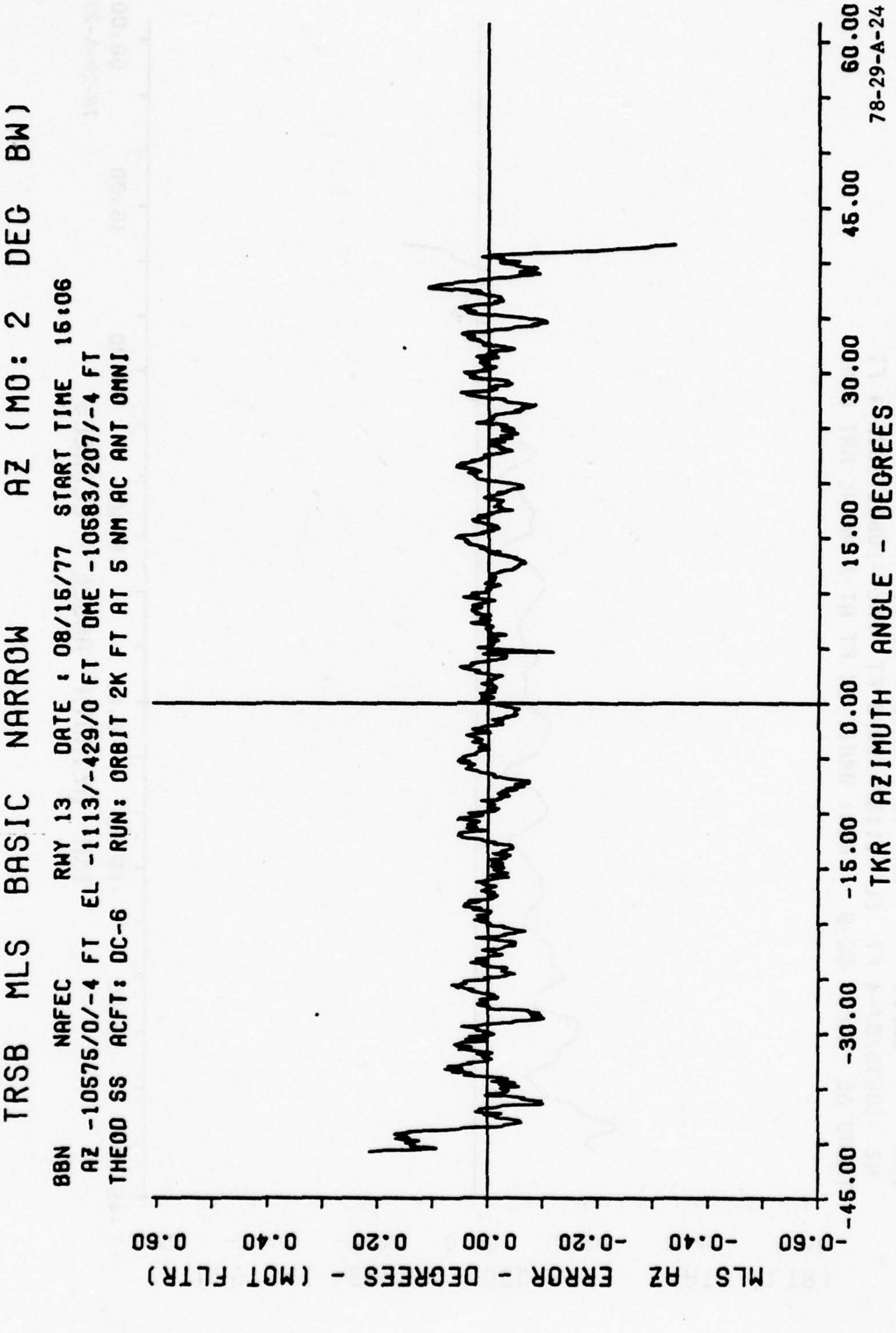
BBN NAFEC RWY 13 DATE : 08/15/77 START TIME 15:06
AZ -10575/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT
THEOD SS ACFT: DC-6 RUN: ORBIT 2K FT AT 5 NM AC ANT OMNI



78-29-A-21


TRSB MLS BASIC NARROW AZ (MO: 2 DEG BW)
BBN NAFEC RWY 13 DATE : 08/16/77 START TIME 16:06
AZ -10575/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT
THEOD SS ACFT: DC-6 RUN: ORBIT 2K FT AT 5 NM AC ANT OMNI
MLS AZ ERROR - DEG - (MEAN / 2SD)
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
TKR AZIMUTH ANGLE - DEGREES
-45.00
-30.00
-15.00
0.00
15.00
30.00
45.00
60.00
78-29-A-22

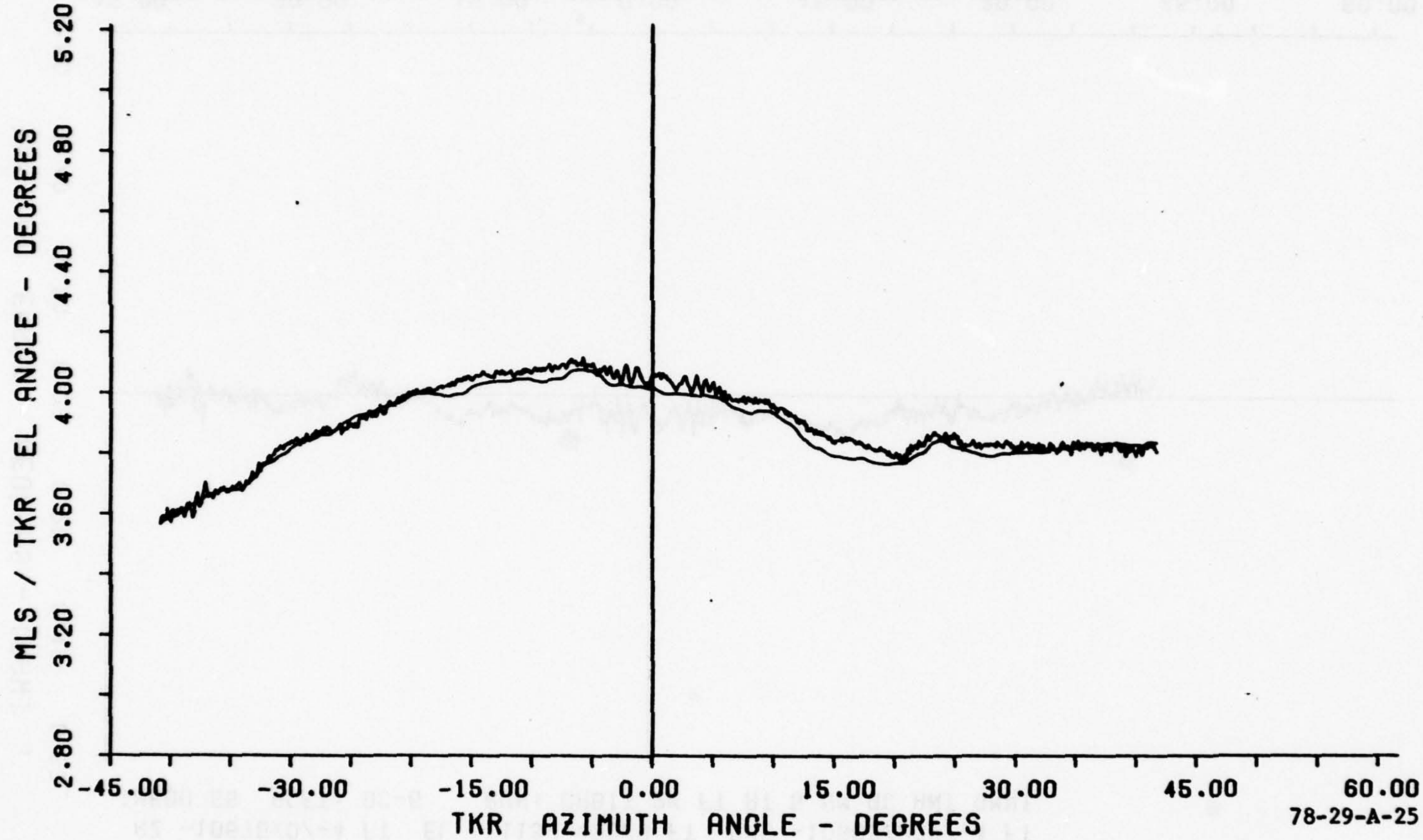

TRSB MLS BASIC NARROW AZ (MO: 2 DEG BW)
BBN NAFEC RWY 13 DATE : 08/16/77 START TIME 16:06
AZ -10676/0/-4 FT EL -1113/-429/0 FT DME -10683/207/-4 FT
THEOD SS ACFT: DC-6 RUN: ORBIT 2K FT AT 5 NM AC ANT OMNI
MLS AZ ERROR - DEGREES - (PATH FLTR)
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-45.00
-30.00
-15.00
0.00
15.00
30.00
45.00
60.00
TKR AZIMUTH ANGLE - DEGREES
78-29-A-23

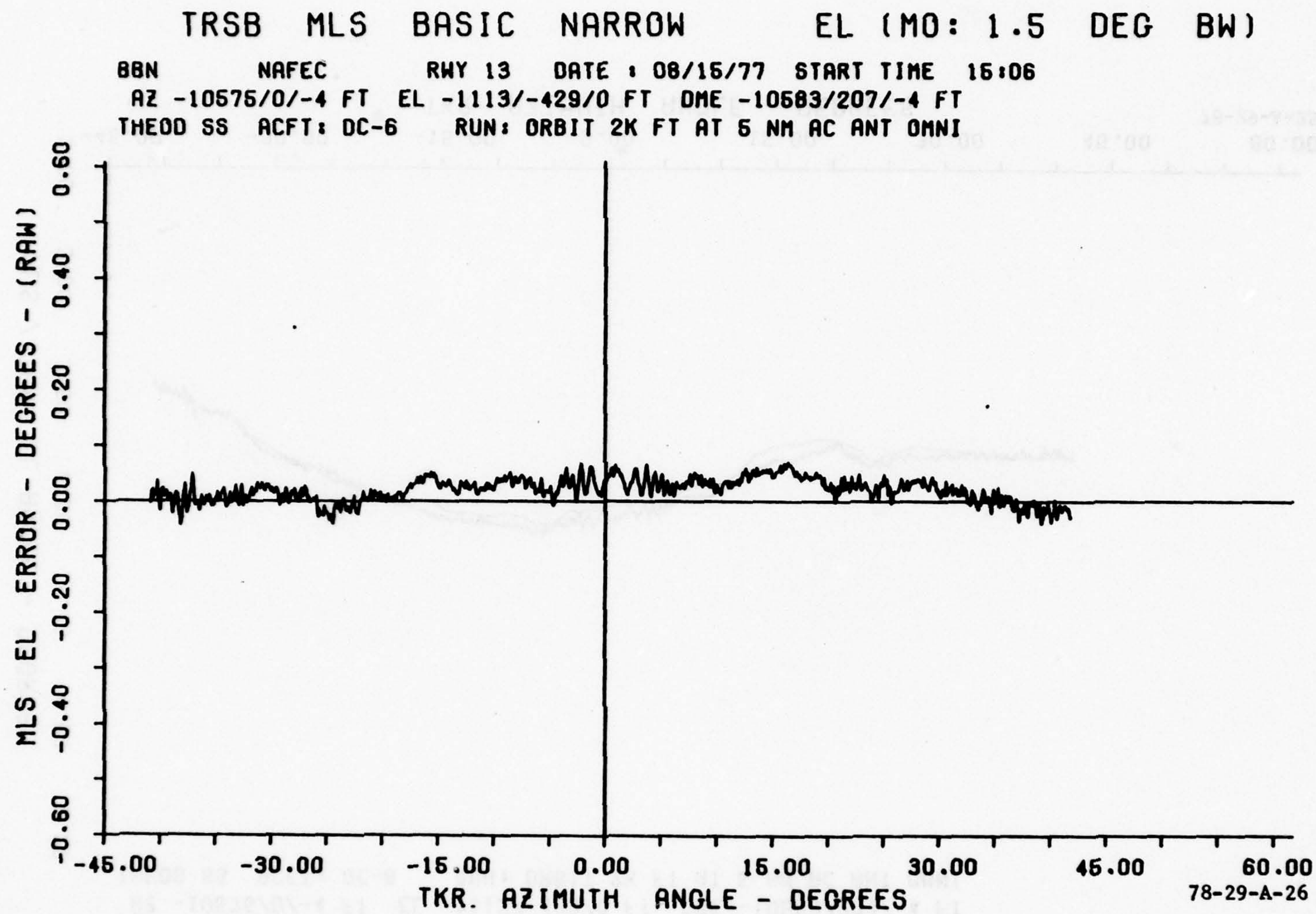


TRSB MLS BASIC NARROW AZ (MO: 2 DEG BW)
BBN NAFEC RWY 13 DATE : 08/16/77 START TIME 16:06
AZ -10575/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT
THEOD SS ACFT: DC-6 RUN: ORBIT 2K FT AT 5 NM AC ANT OMNI
MLS AZ ERROR - DEGREES - (MOT FLTR)
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-45.00
-30.00
-15.00
0.00
15.00
30.00
45.00
60.00
TKR AZIMUTH ANGLE - DEGREES
78-29-A-24

TRSB MLS BASIC NARROW EL (MO: 1.5 DEG BW)

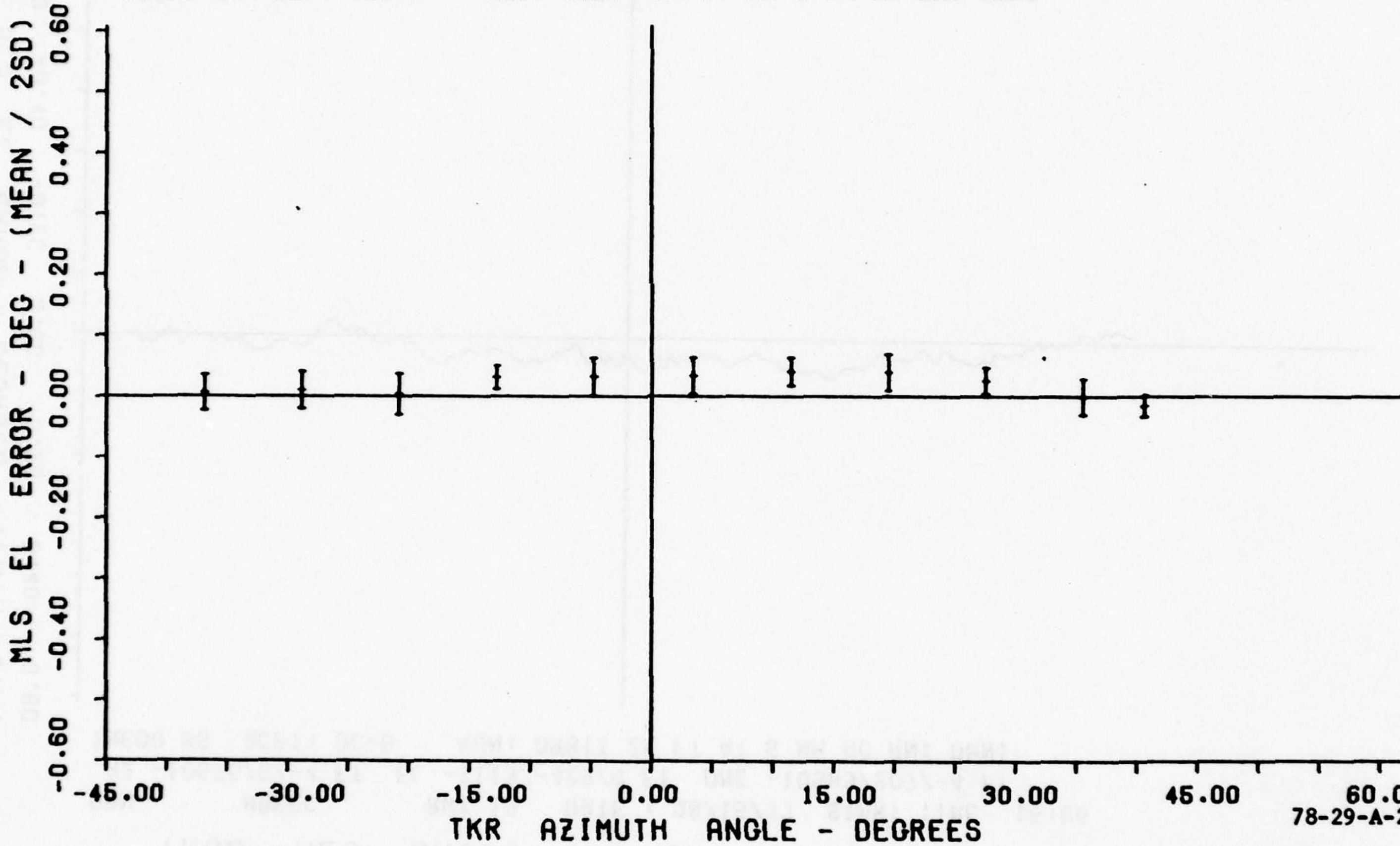
BBN NAFEC RWY 13 DATE : 08/15/77 START TIME 15:06
AZ -10576/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT
THEOD SS ACFT: DC-6 RUN: ORBIT 2K FT AT 5 NM AC ANT OMNI



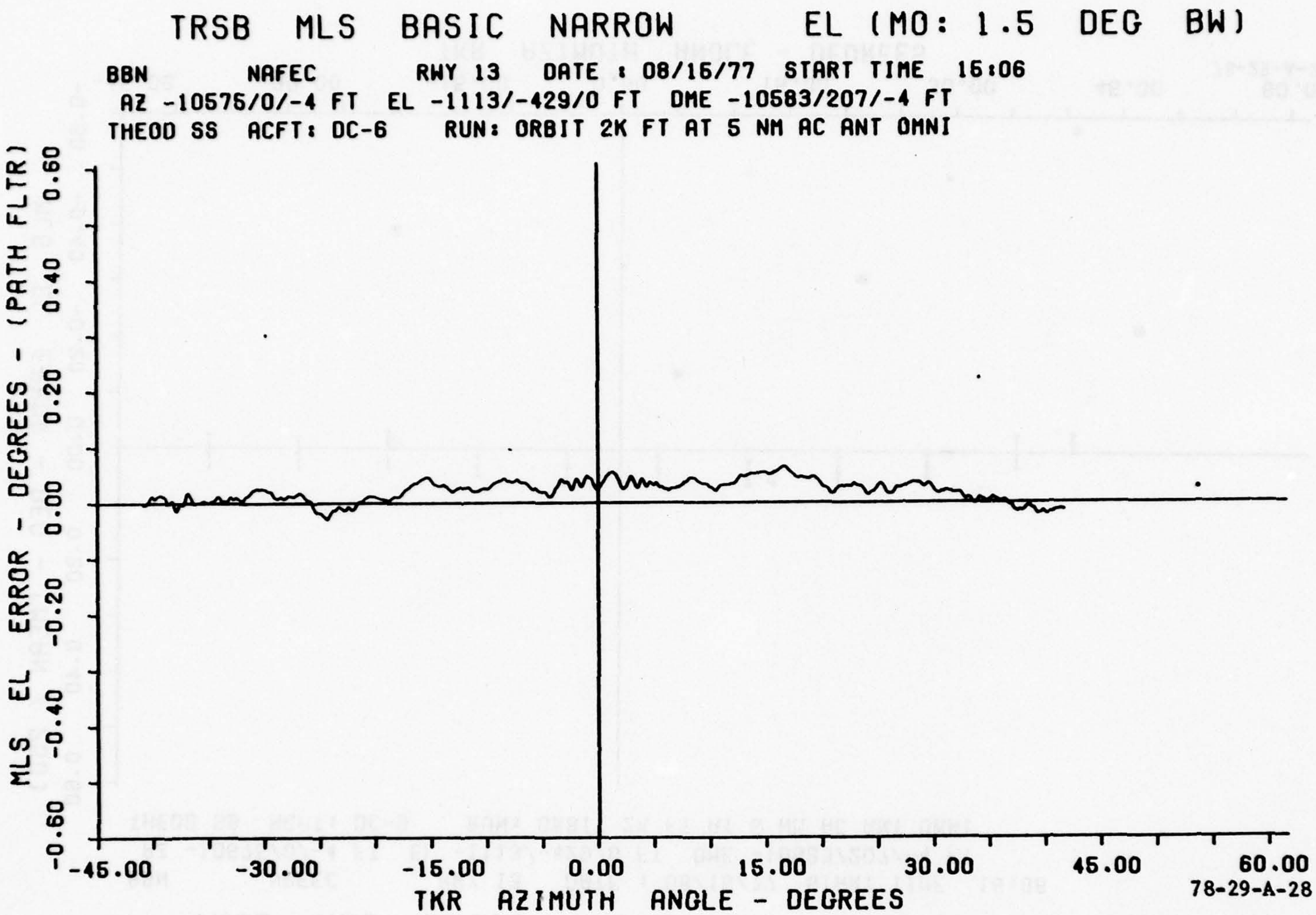

TRSB MLS BASIC NARROW EL (MO: 1.5 DEG BW)
BBN NAFEC RWY 13 DATE : 08/15/77 START TIME 15:06
AZ -10575/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT
THEOD SS ACFT: DC-6 RUN: ORBIT 2K FT AT 5 NM AC ANT OMNI
MLS EL ERROR - DEGREES - (RAW)
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-45.00
-30.00
-15.00
0.00
15.00
30.00
45.00
60.00
TKR. AZIMUTH ANGLE - DEGREES
78-29-A-26

TRSB MLS BASIC NARROW EL (MO: 1.5 DEG BW)

BBN NAFEC RWY 13 DATE : 08/15/77 START TIME 15:06
AZ -10575/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT
THEOD SS ACFT: DC-6 RUN: ORBIT 2K FT AT 5 NM AC ANT OMNI

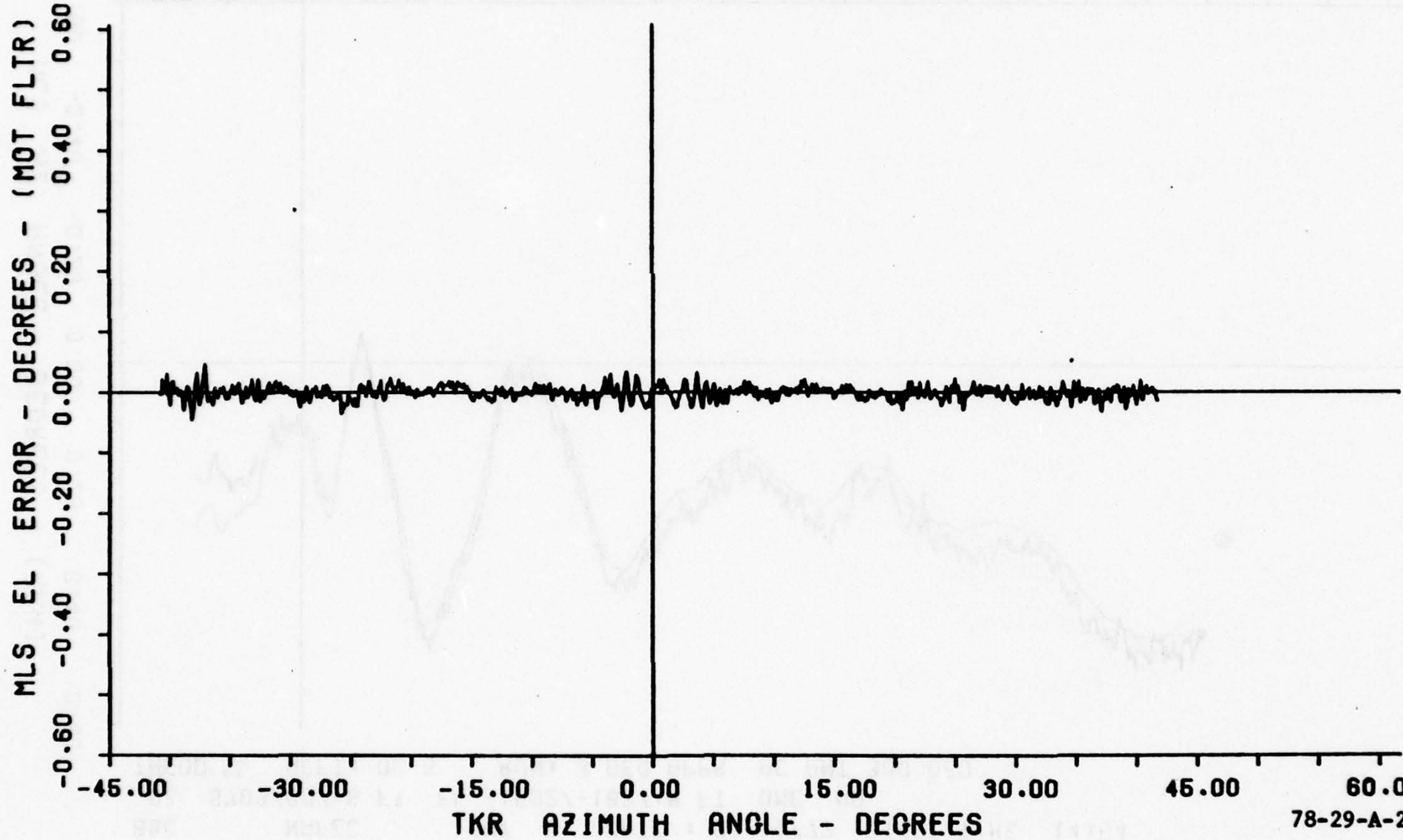


78-29-A-27

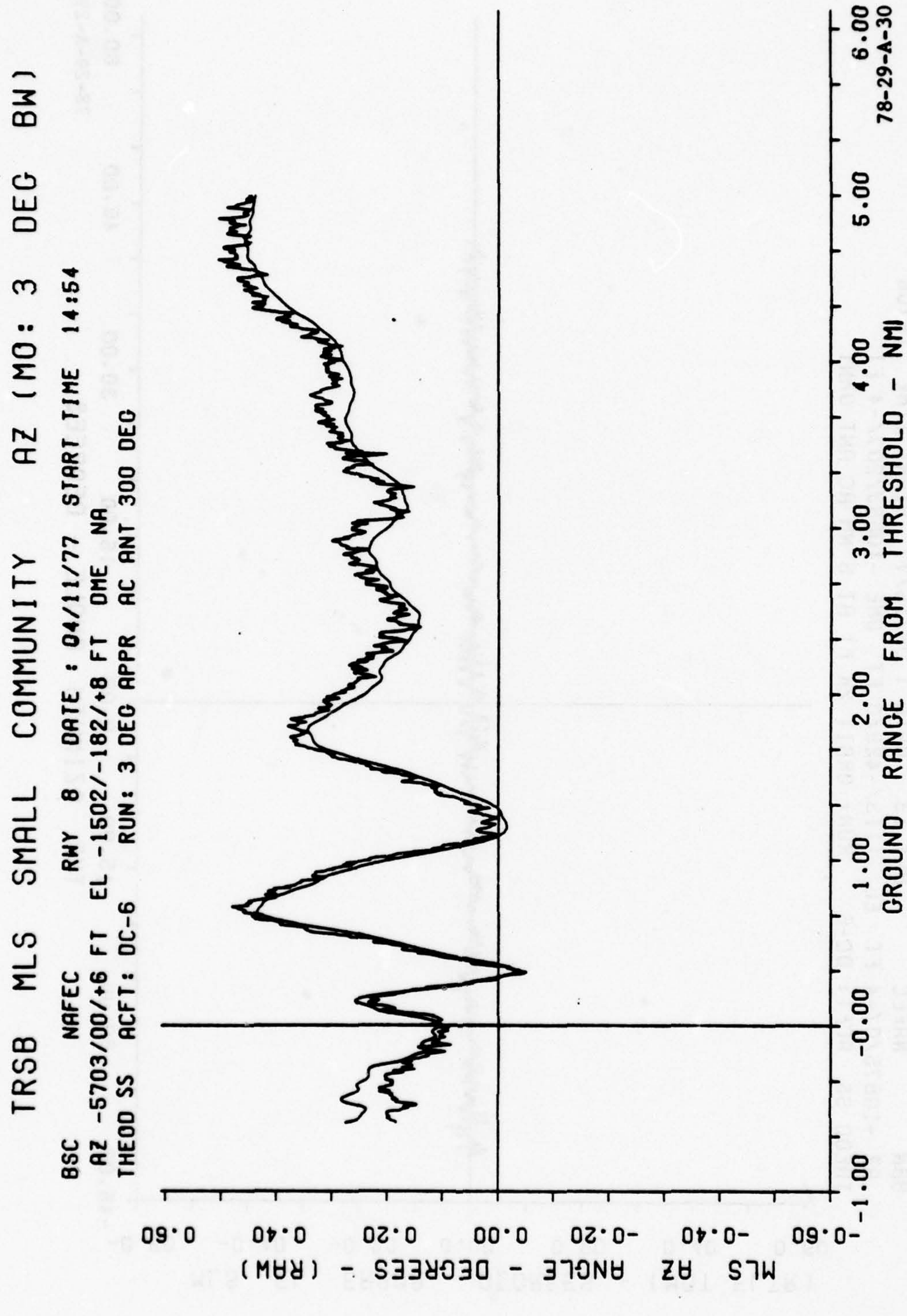

TRSB MLS BASIC NARROW EL (MO: 1.5 DEG BW)
BBN NAFEC RWY 13 DATE : 08/16/77 START TIME 16:06
AZ -10576/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT
THEOD SS ACFT: DC-6 RUN: ORBIT 2K FT AT 5 NM AC ANT OMNI
MLS EL ERROR - DEGREES - (PATH FLTR)
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-45.00
-30.00
-15.00
0.00
15.00
30.00
45.00
60.00
TKR AZIMUTH ANGLE - DEGREES
78-29-A-28

TRSB MLS BASIC NARROW EL (MO: 1.5 DEG BW)

BBN NAFEC RWY 13 DATE : 08/16/77 START TIME 16:06
AZ -10675/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT
THEOD SS ACFT: DC-6 RUN: ORBIT 2K FT AT 5 NM AC ANT OMNI



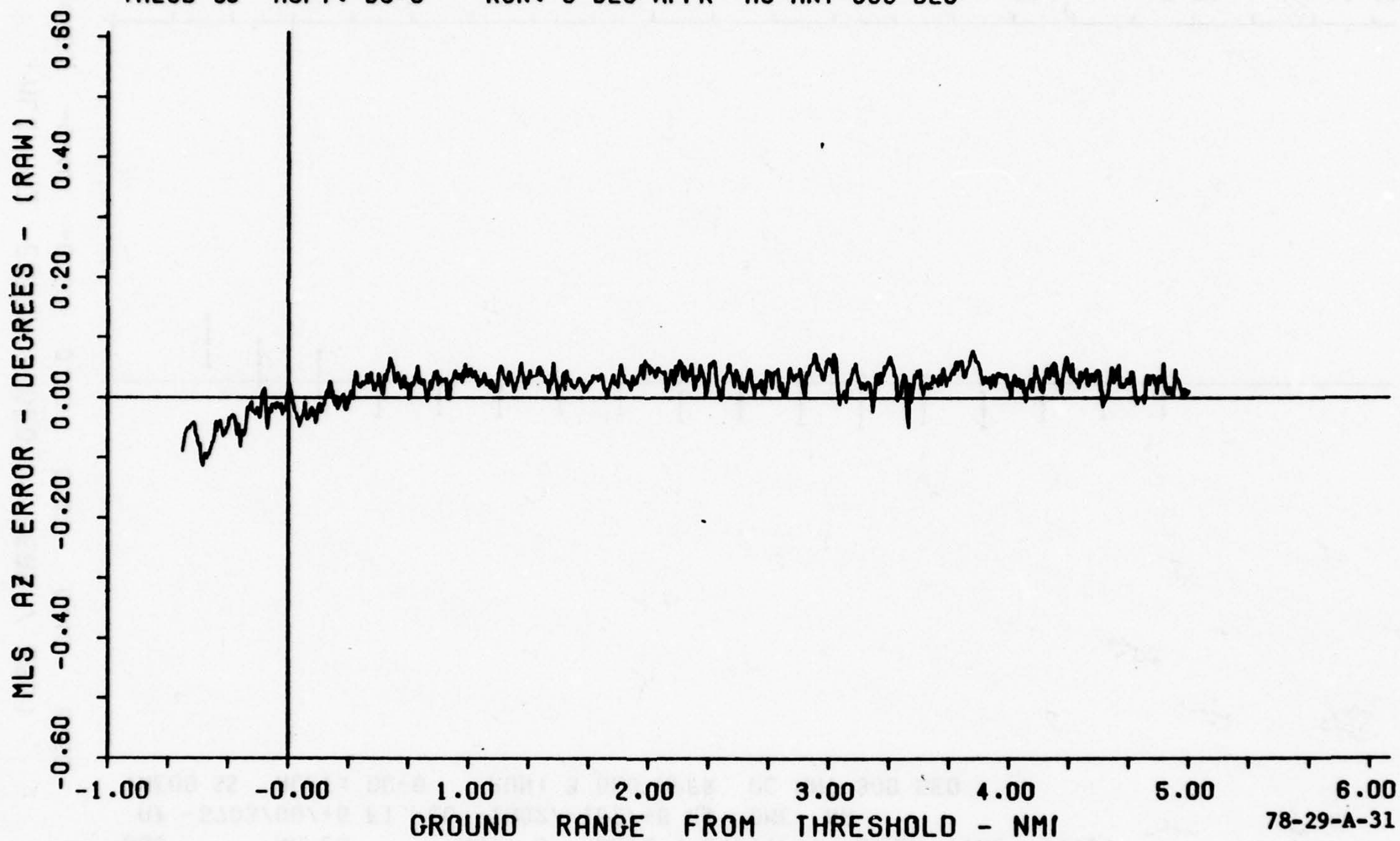
78-29-A-29



TRSB MLS SMALL COMMUNITY AZ (MO: 3 DEG BW)
BSC NAFEC RWY 8 DATE : 04/11/77 START TIME 14:54
AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
THEOD SS ACFT: DC-6 RUN: 3 DEG APPR AC ANT 300 DEG
MLS AZ ANGLE - DEGREES - (RAW)
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-1.00
-0.00
1.00
2.00
3.00
4.00
5.00
6.00
GROUND RANGE FROM THRESHOLD - NMI
78-29-A-30

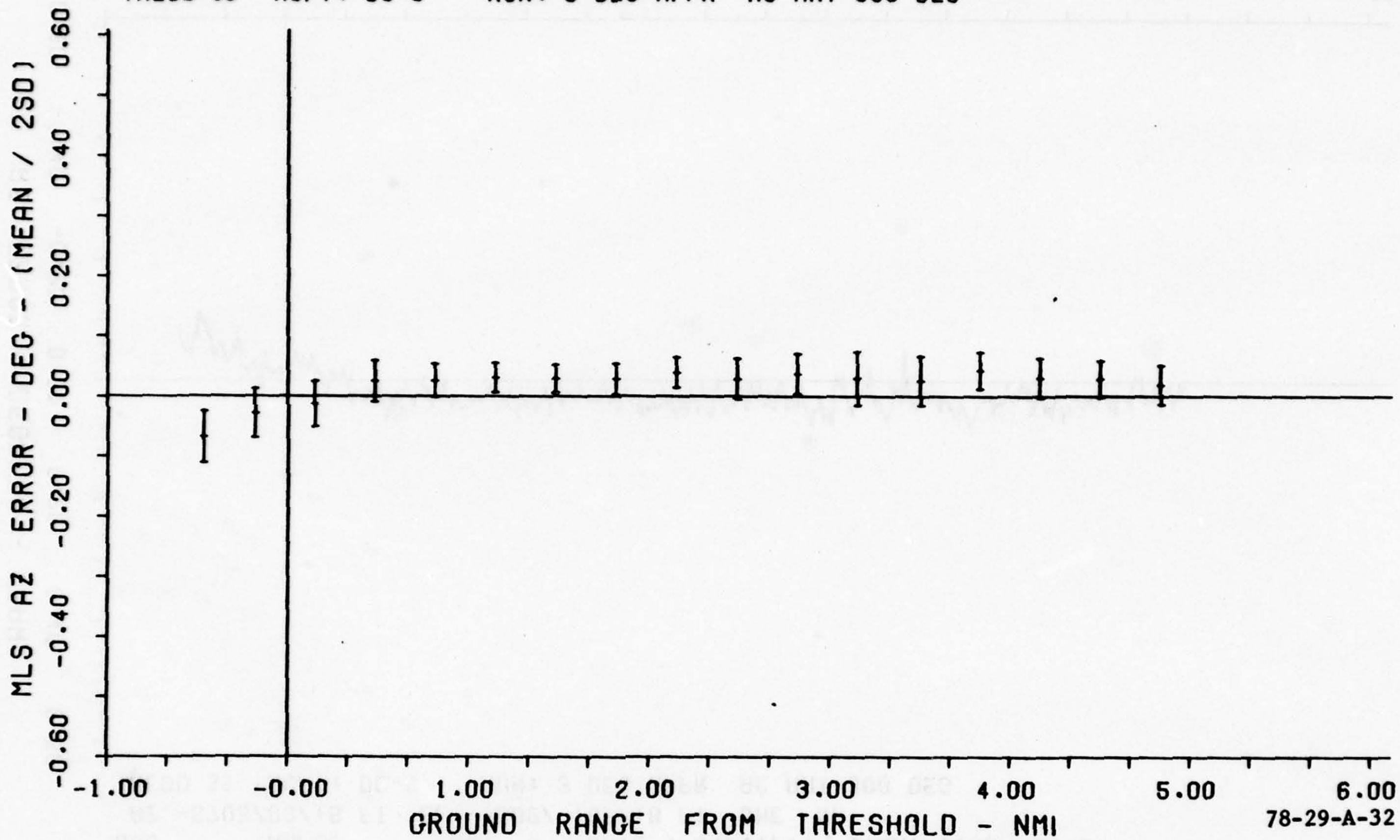
TRSB MLS SMALL COMMUNITY AZ (MO: 3 DEG BW)

BSC NAFEC RWY 8 DATE : 04/11/77 . START TIME 14:54
AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
THEOD SS ACFT: DC-6 RUN: 3 DEG APPR AC ANT 300 DEG

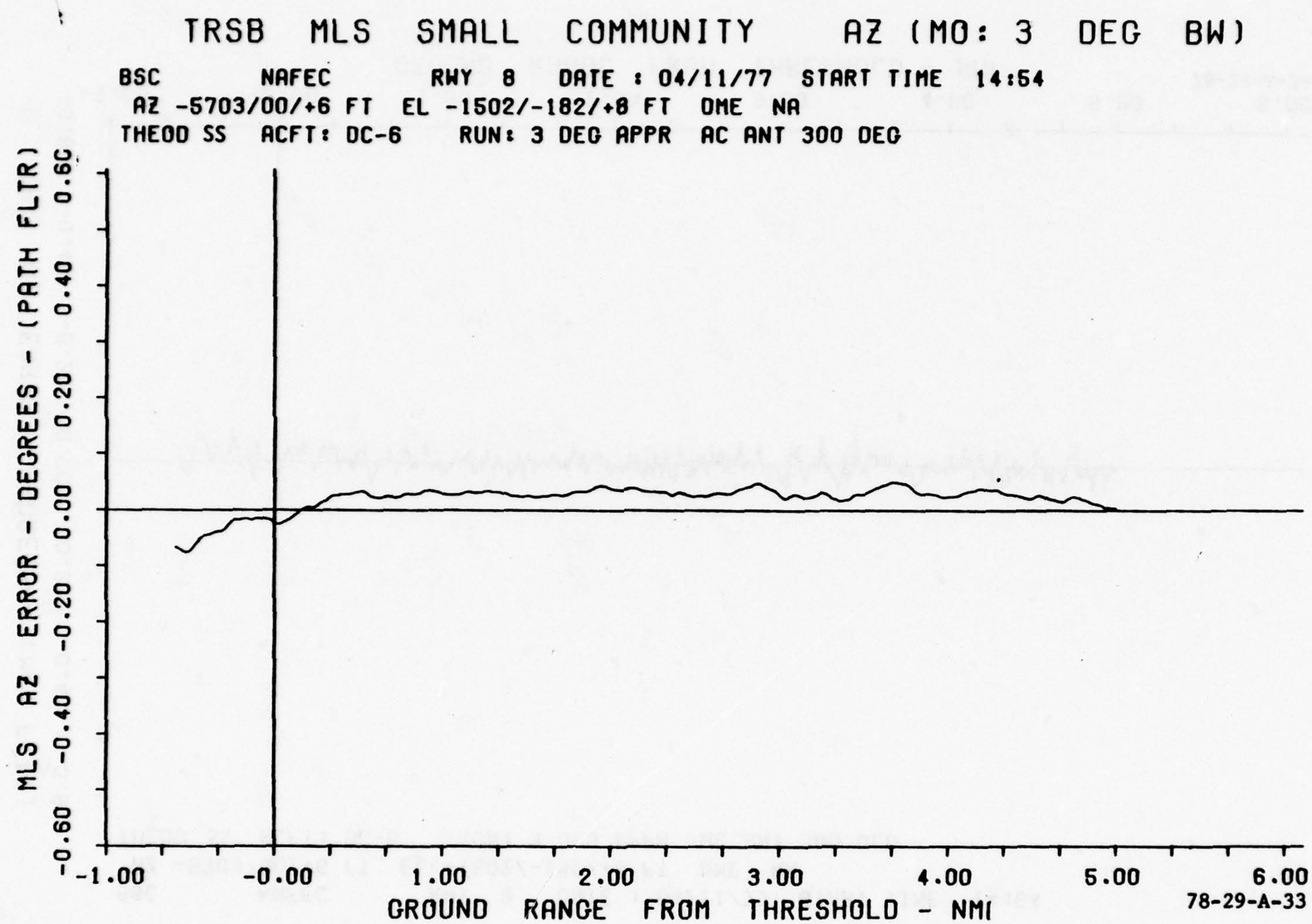


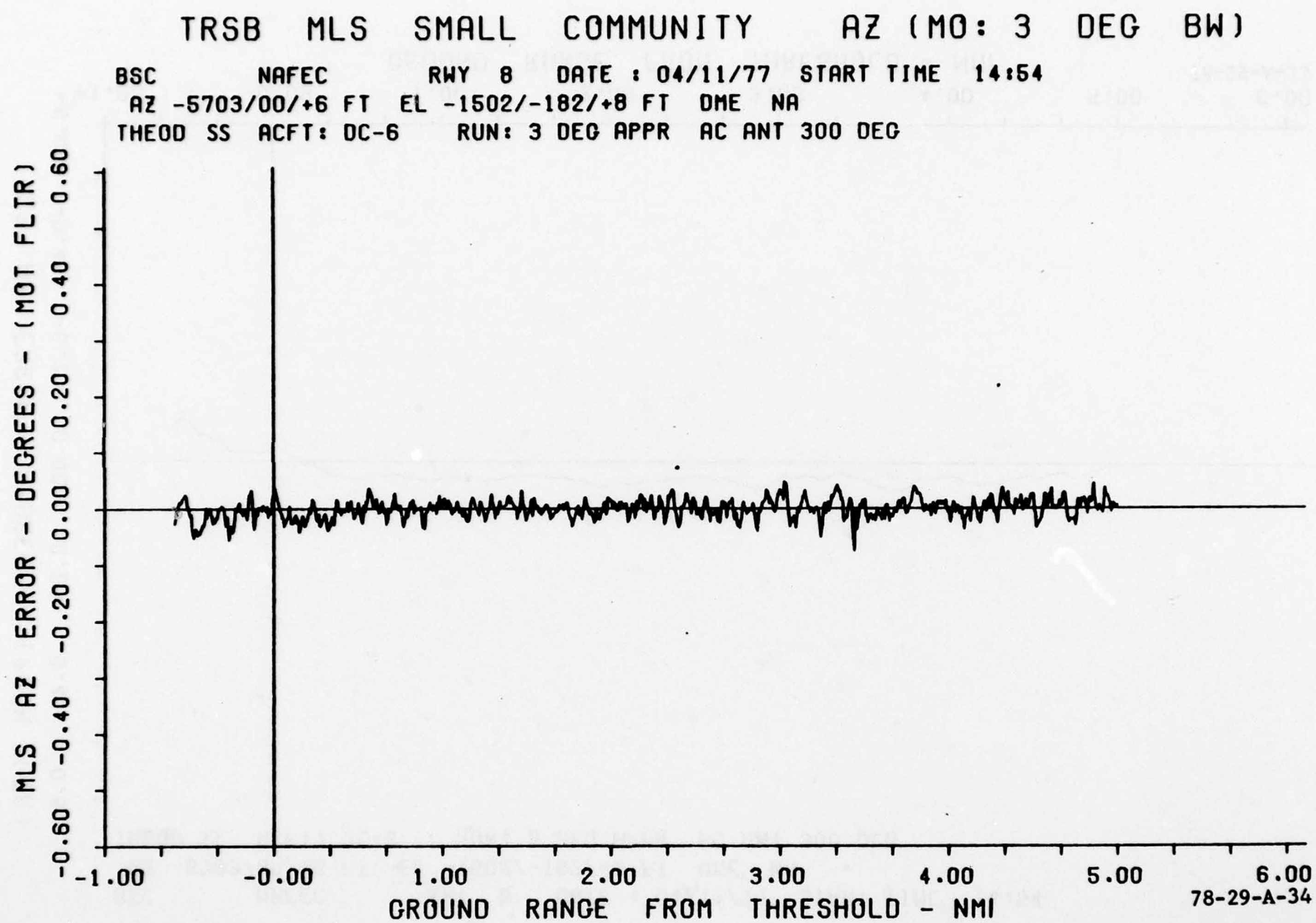
TRSB MLS SMALL COMMUNITY AZ (MO: 3 DEG BW)

BSC NAFEC RWY 8 DATE : 04/11/77 START TIME 14:54
AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
THEOD SS ACFT: DC-6 RUN: 3 DEG APPR AC ANT 300 DEG



78-29-A-32

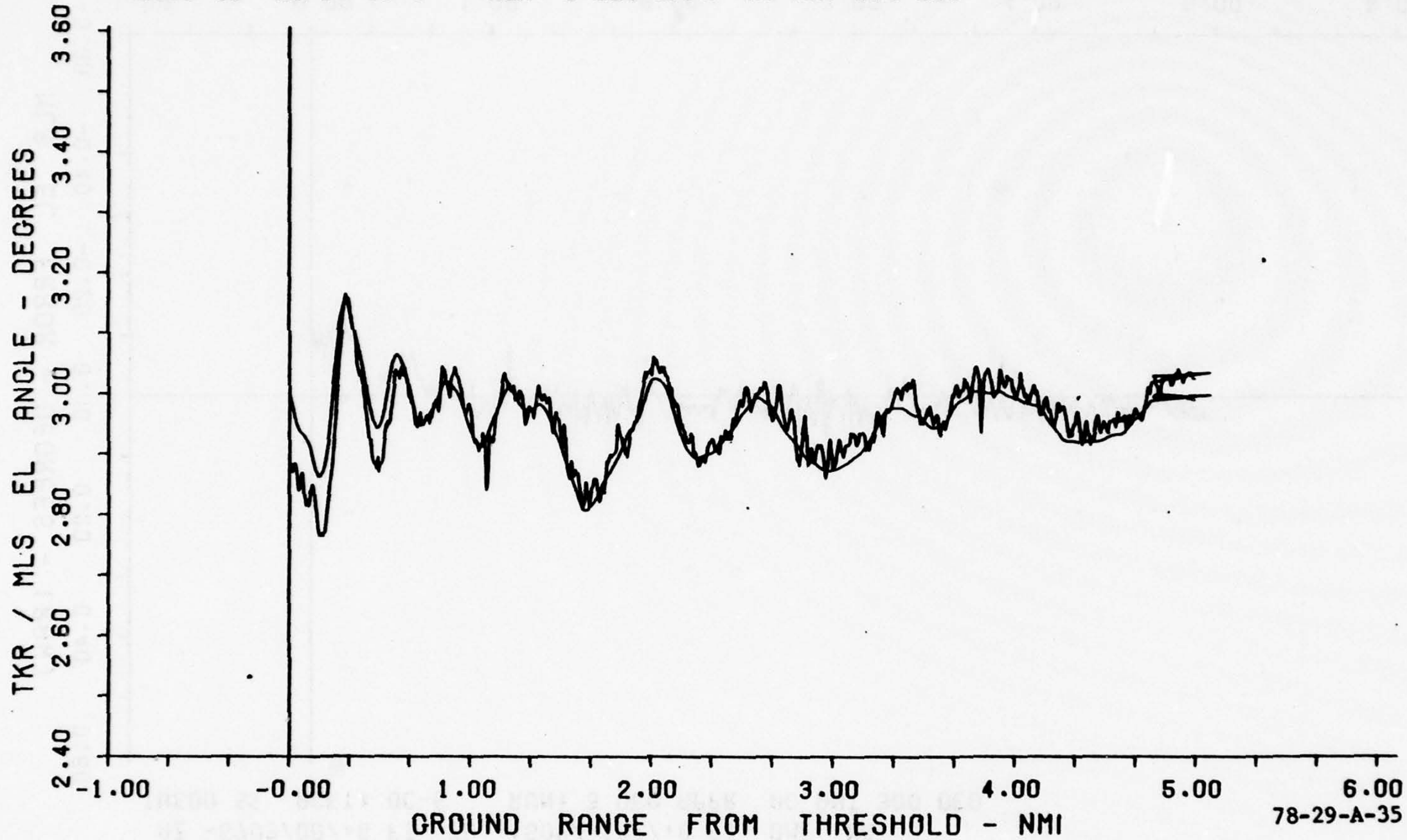

TRSB MLS SMALL COMMUNITY AZ (MO: 3 DEG BW)
BSC NAFEC RWY 8 DATE : 04/11/77 START TIME 14:54
AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
THEOD SS ACFT: DC-6 RUN: 3 DEG APPR AC ANT 300 DEG
MLS AZ ERROR - DEGREES - (PATH FLTR)
0.6C
0.40
0.20
0.00
-0.20
-0.40
-0.60
-1.00
-0.00
1.00
2.00
3.00
4.00
5.00
6.00
GROUND RANGE FROM THRESHOLD - NMI
78-29-A-33



TRSB MLS SMALL COMMUNITY AZ (MO: 3 DEG BW)
BSC NAFEC RWY 8 DATE : 04/11/77 START TIME 14:54
AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
THEOD SS ACFT: DC-6 RUN: 3 DEG APPR AC ANT 300 DEG
MLS AZ ERROR - DEGREES - (MOT FLTR)
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-1.00
-0.00
1.00
2.00
3.00
4.00
5.00
6.00
GROUND RANGE FROM THRESHOLD - NMI
78-29-A-34

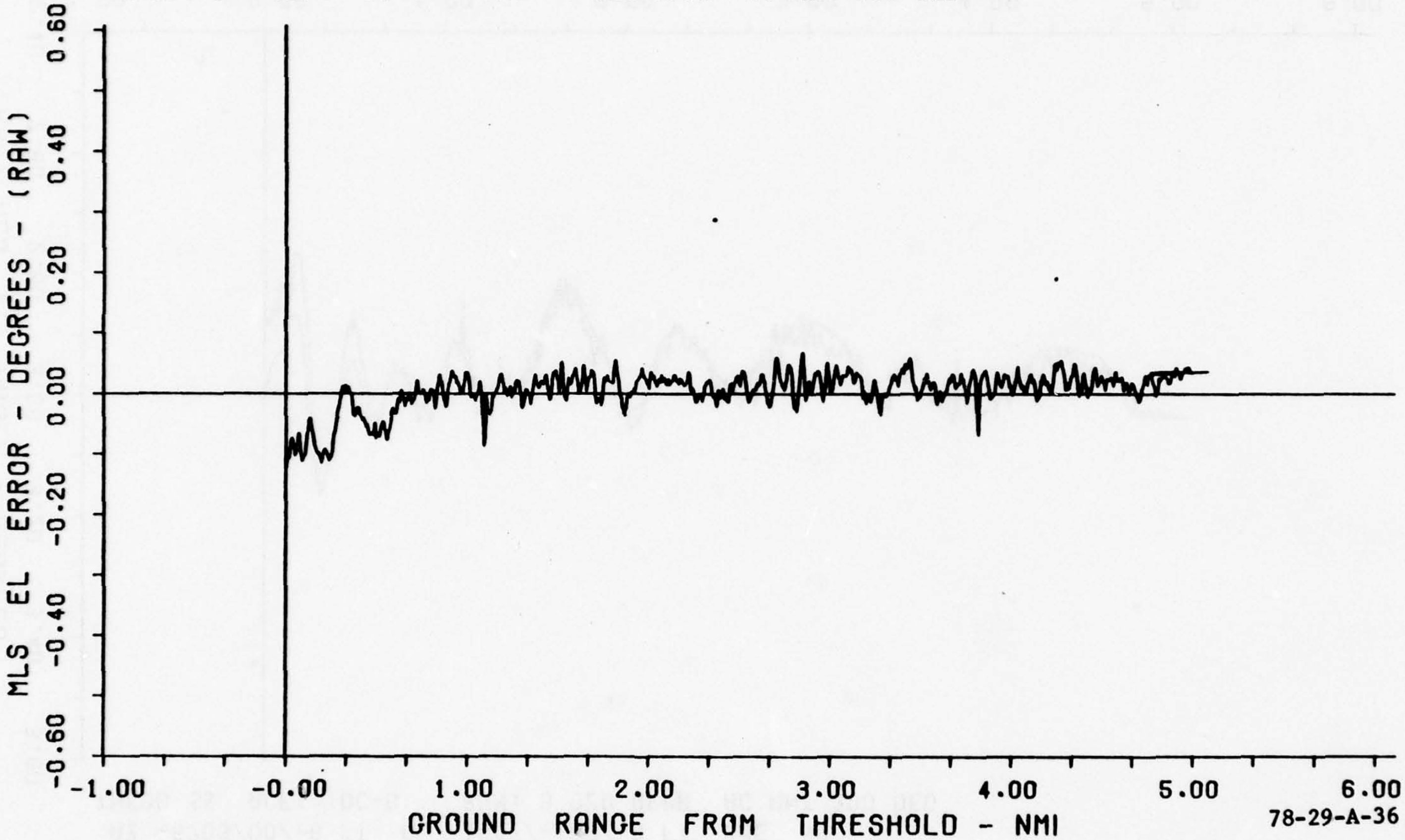
TRSB MLS SMALL COMMUNITY EL (MO: 2 DEG BW)

BSC NAFEC RWY 8 DATE : 04/11/77 START TIME 14:54
AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
THEOD SS ACFT: DC-6 RUN: 3 DEG APPR AC ANT 300 DEG



TRSB MLS SMALL COMMUNITY EL (MO: 2 DEG BW)

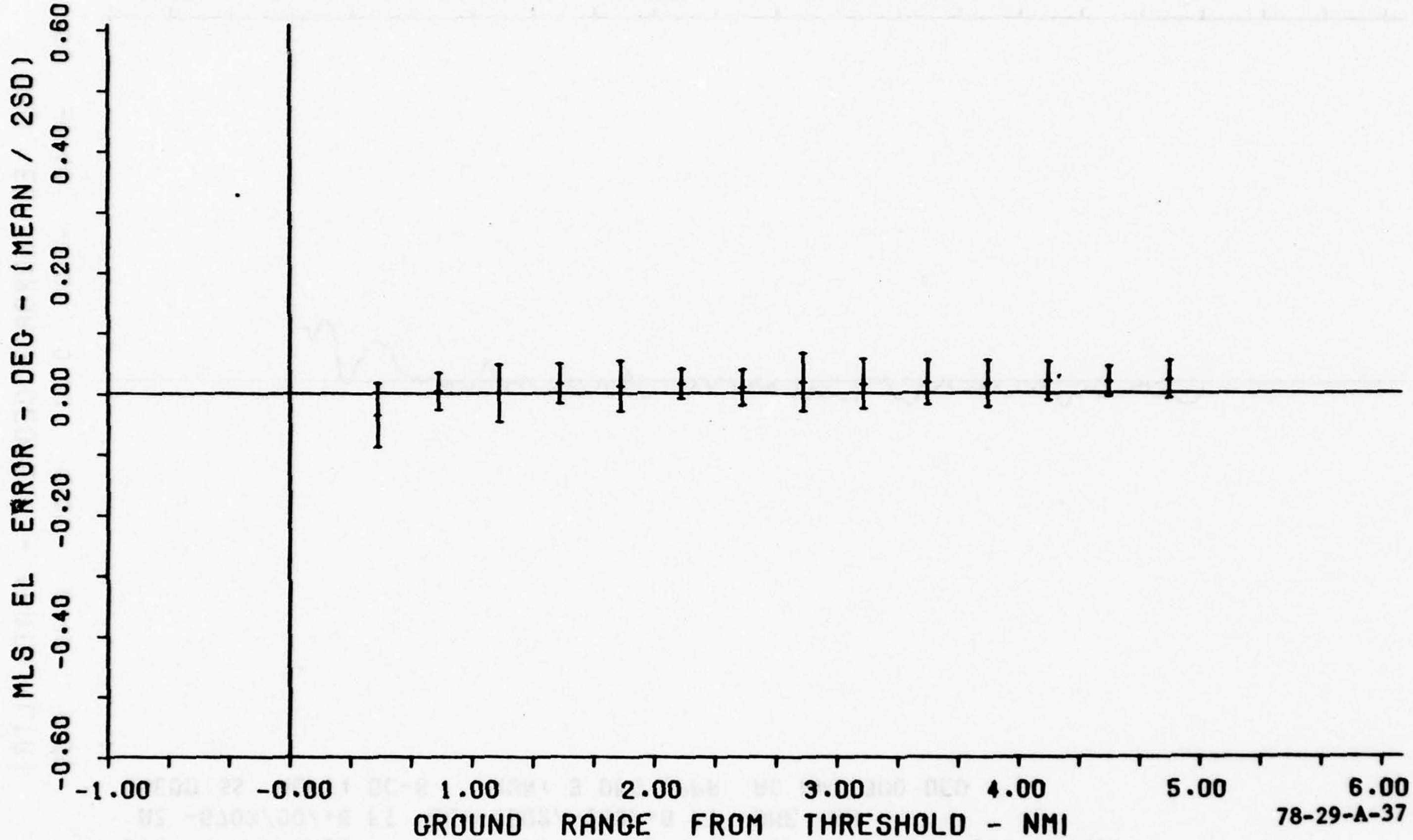
BSC NAFEC RWY 8 DATE : 04/11/77 START TIME 14:54
AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
THEOD SS ACFT: DC-6 RUN: 3 DEG APPR AC ANT 300 DEG



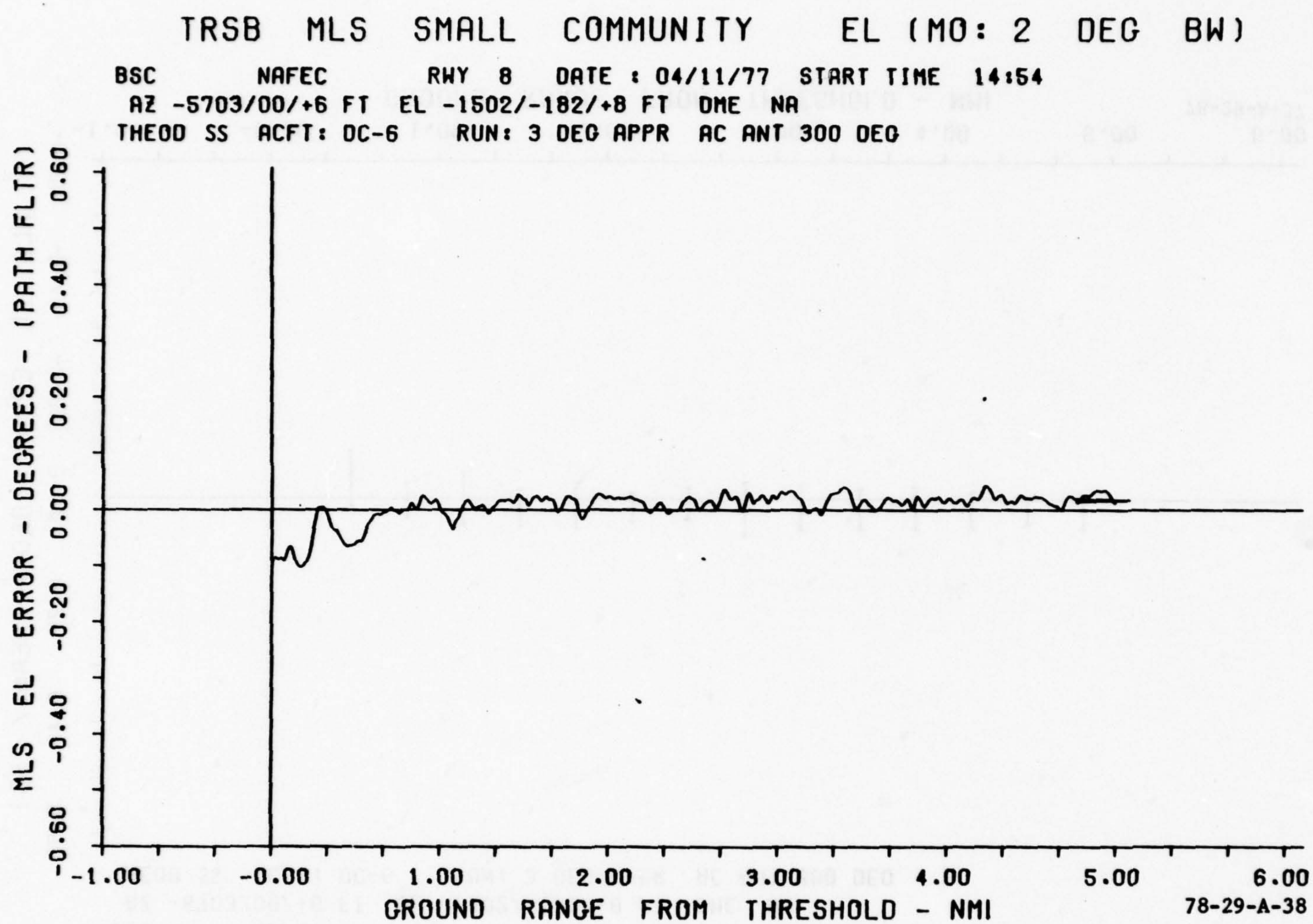
78-29-A-36

TRSB MLS SMALL COMMUNITY EL (MO: 2 DEG BW)

BSC NAFEC RWY 8 DATE : 04/11/77 START TIME 14:54
AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
THEOD SS ACFT: DC-6 RUN: 3 DEG APPR AC ANT 300 DEG



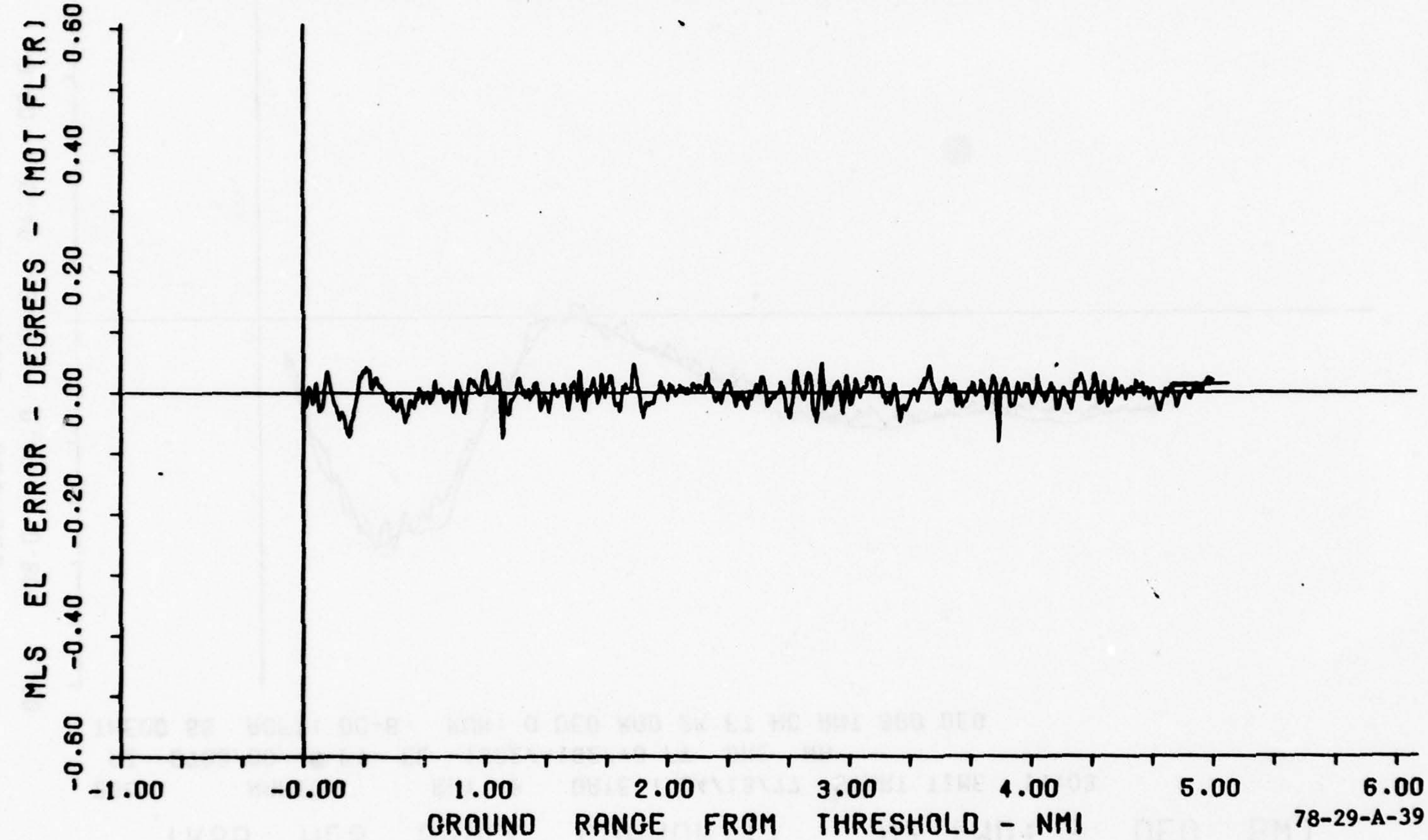
78-29-A-37


TRSB MLS SMALL COMMUNITY EL (MO: 2 DEG BW)
BSC NAFEC RWY 8 DATE : 04/11/77 START TIME 14:54
AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
THEOD SS ACFT: DC-6 RUN: 3 DEG APPR AC ANT 300 DEG
MLS EL ERROR - DEGREES - (PATH FLTR)
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-1.00
-0.00
1.00
2.00
3.00
4.00
5.00
6.00
GROUND RANGE FROM THRESHOLD - NMI

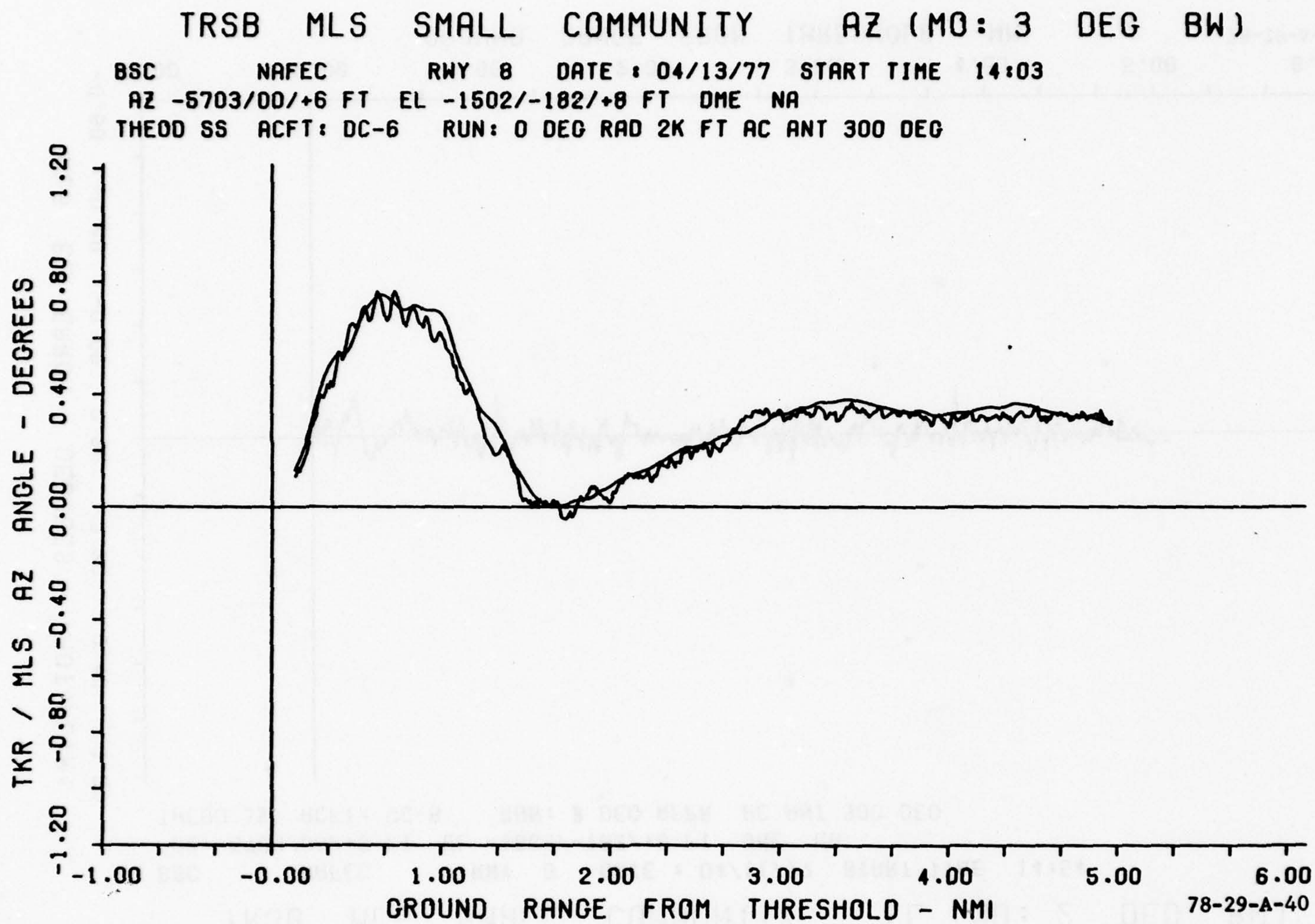
78-29-A-38

TRSB MLS SMALL COMMUNITY EL (MO: 2 DEG BW)

BSC NAFEC RWY 8 DATE : 04/11/77 START TIME 14:54
AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
THEOD SS ACFT: DC-6 RUN: 3 DEG APPR AC ANT 300 DEG

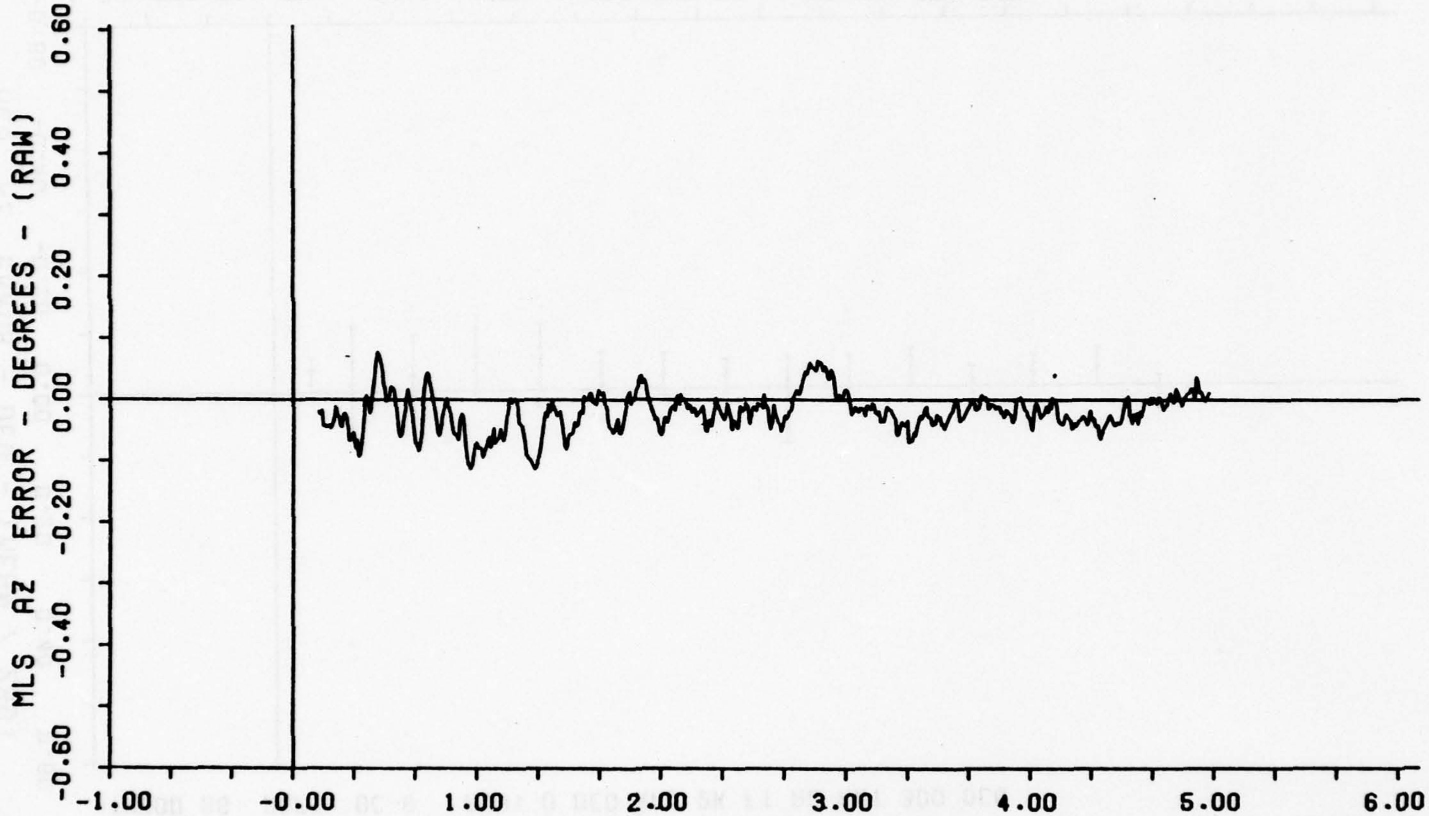


78-29-A-39

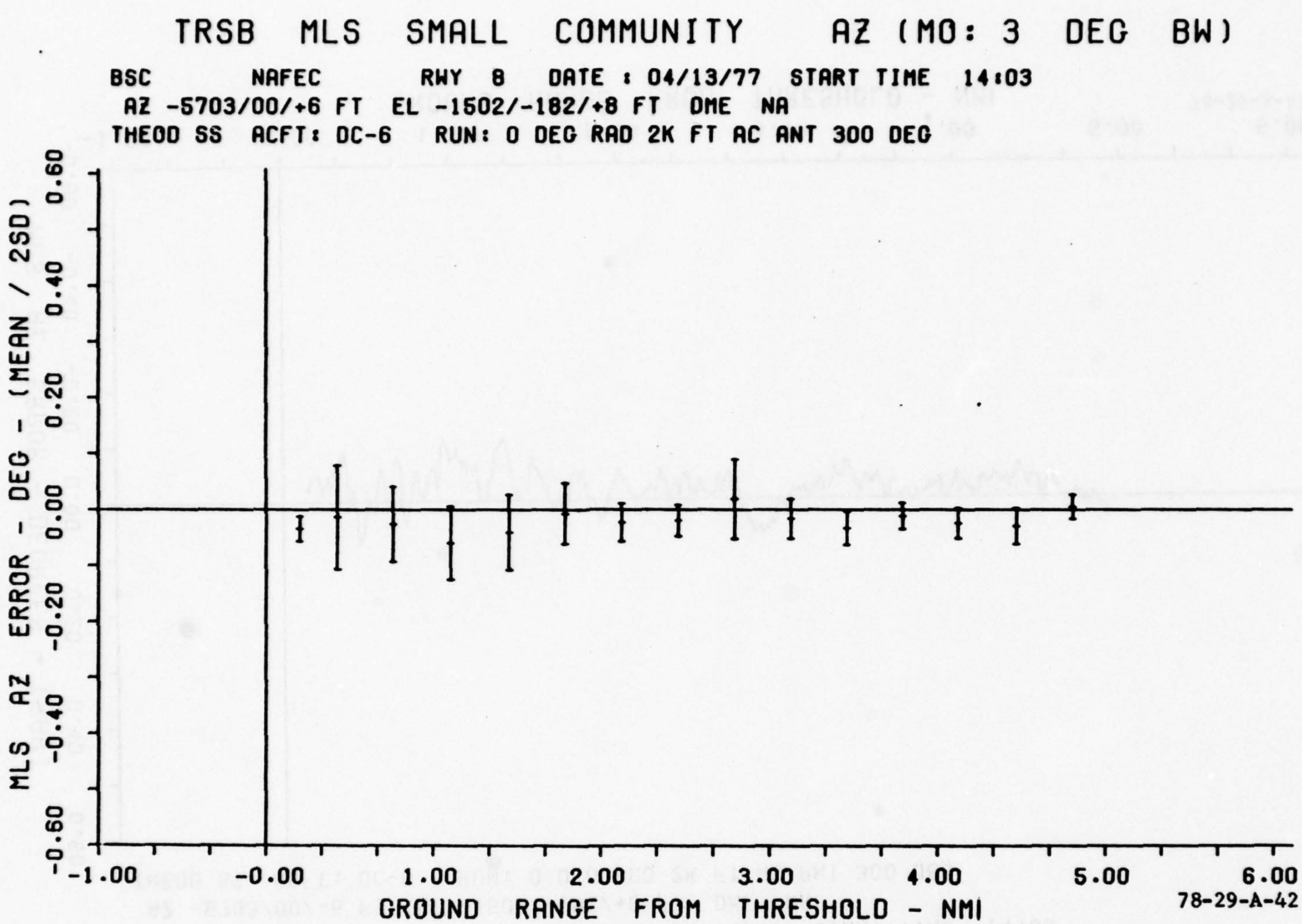

TRSB MLS SMALL COMMUNITY AZ (MO: 3 DEG BW)
BSC NAFEC RWY 8 DATE : 04/13/77 START TIME 14:03
AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
THEOD SS ACFT: DC-6 RUN: 0 DEG RAD 2K FT AC ANT 300 DEG
TKR / MLS AZ ANGLE - DEGREES
1.20
0.80
0.40
0.00
-0.40
-0.80
-1.20
-1.00
-0.00
1.00
2.00
3.00
4.00
5.00
6.00
GROUND RANGE FROM THRESHOLD - NMI
78-29-A-40

TRSB MLS SMALL COMMUNITY AZ (MO: 3 DEG BW)

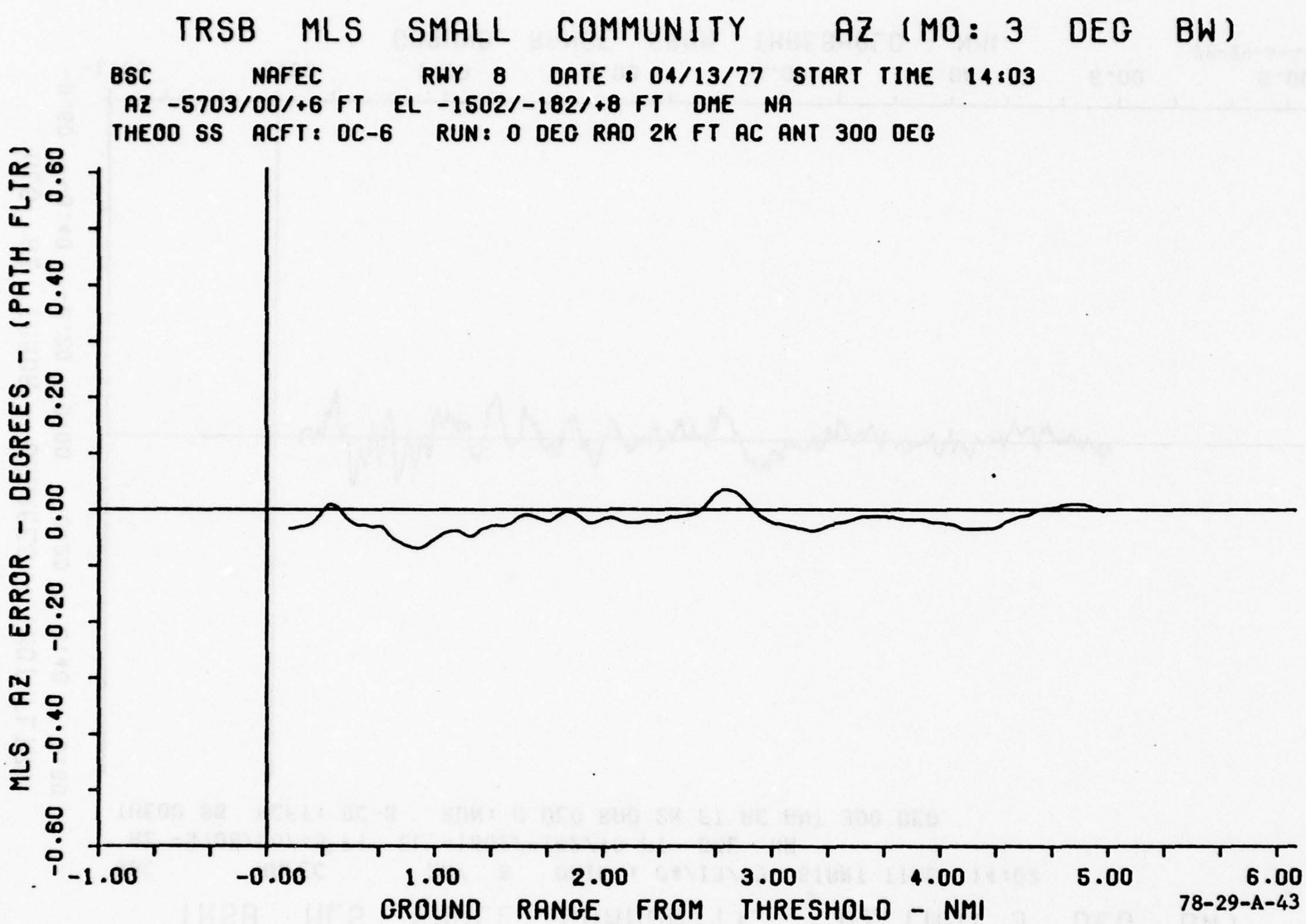
BSC NAFEC RWY 8 DATE : 04/13/77 START TIME 14:03
AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
THEOD SS ACFT: DC-6 RUN: 0 DEG RAD 2K FT AC ANT 300 DEG



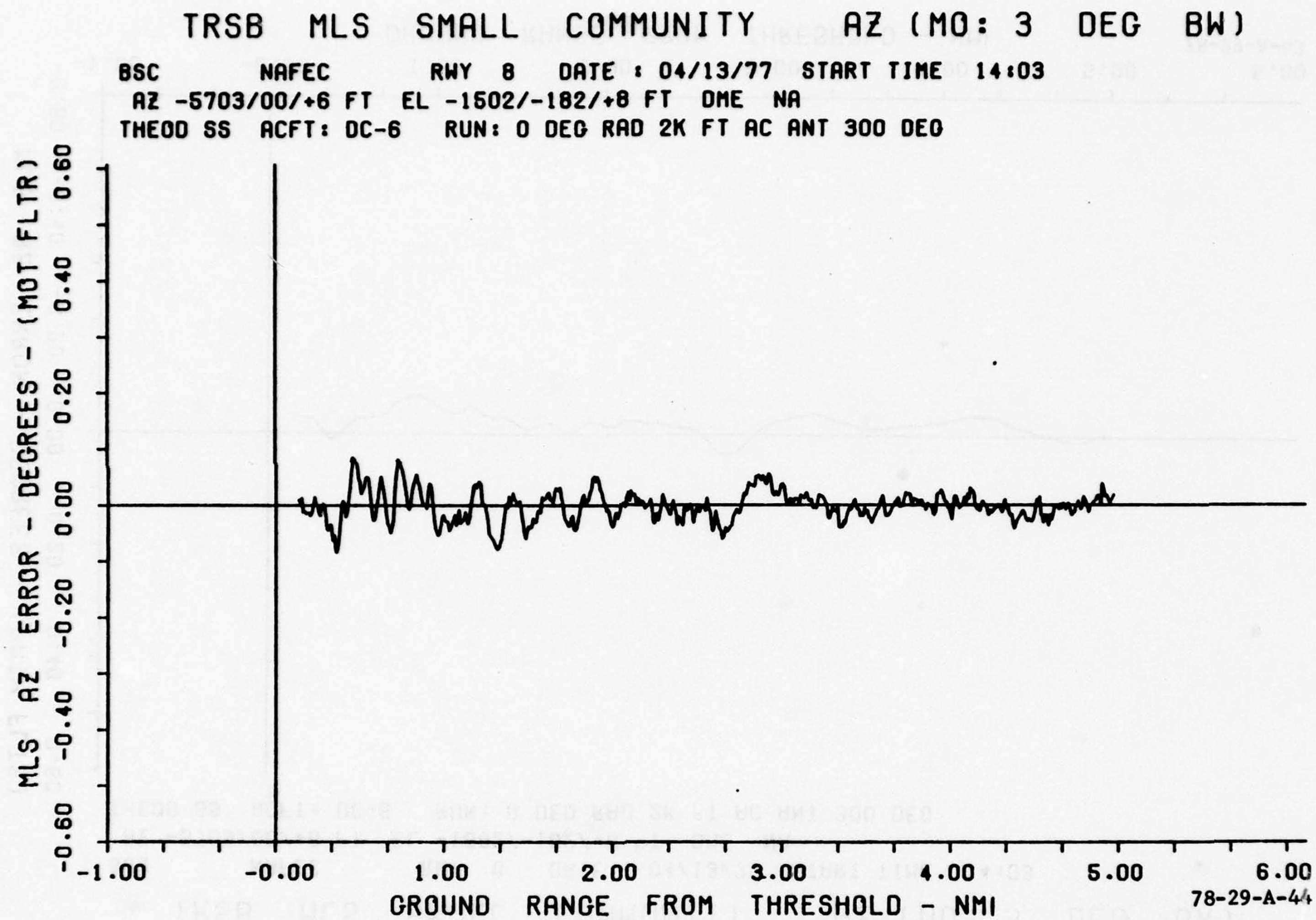
78-29-A-41



TRSB MLS SMALL COMMUNITY AZ (MO: 3 DEG BW)
BSC NAFEC RWY 8 DATE : 04/13/77 START TIME 14:03
AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
THEOD SS ACFT: DC-6 RUN: 0 DEG RAD 2K FT AC ANT 300 DEG
MLS AZ ERROR - DEG - (MEAN / 2SD)
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-1.00
-0.00
1.00
2.00
3.00
4.00
5.00
6.00
GROUND RANGE FROM THRESHOLD - NMI
78-29-A-42

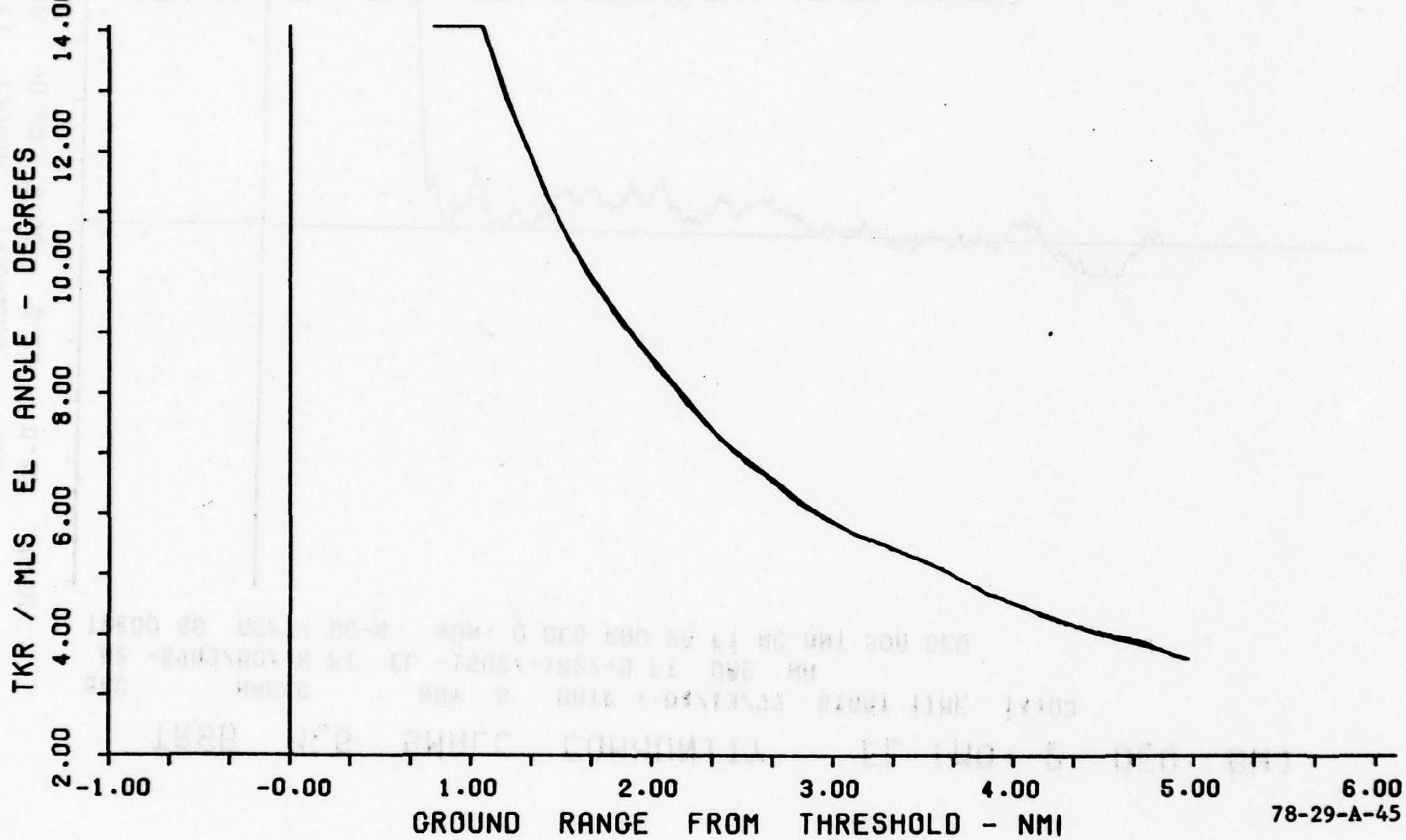


TRSB MLS SMALL COMMUNITY AZ (MO: 3 DEG BW)
BSC NAFEC RWY 8 DATE : 04/13/77 START TIME 14:03
AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
THEOD SS ACFT: DC-6 RUN: 0 DEG RAD 2K FT AC ANT 300 DEG
MLS AZ ERROR - DEGREES - (PATH FLTR)
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-1.00
-0.00
1.00
2.00
3.00
4.00
5.00
6.00
GROUND RANGE FROM THRESHOLD - NMI
78-29-A-43

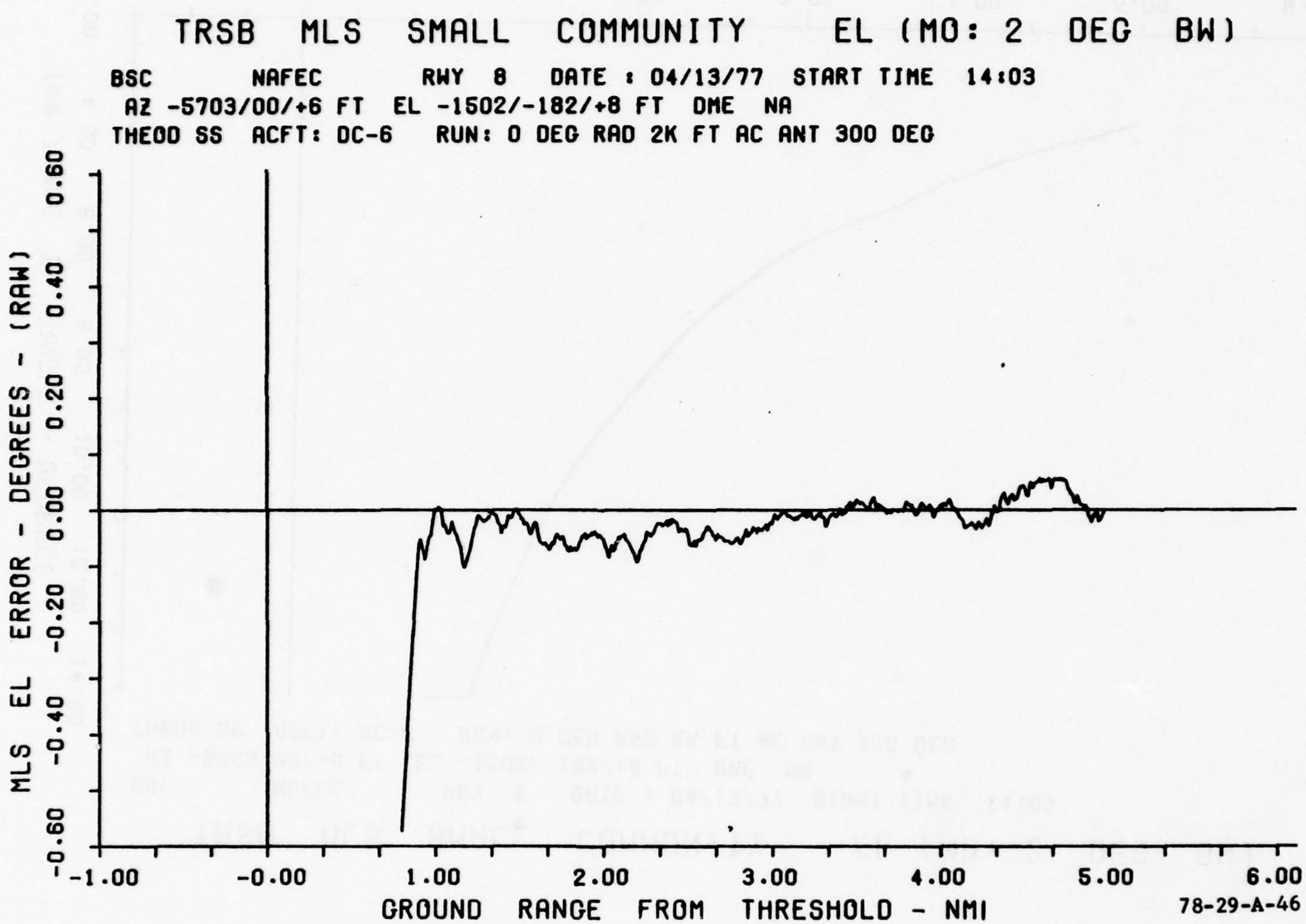

TRSB MLS SMALL COMMUNITY AZ (MO: 3 DEG BW)
BSC NAFEC RWY 8 DATE : 04/13/77 START TIME 14:03
AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
THEOD SS ACFT: DC-6 RUN: 0 DEG RAD 2K FT AC ANT 300 DEG
MLS AZ ERROR - DEGREES - (MOT FLTR)
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-1.00
-0.00
1.00
2.00
3.00
4.00
5.00
6.00
GROUND RANGE FROM THRESHOLD - NMI
78-29-A-44

TRSB MLS SMALL COMMUNITY EL (MO: 2 DEG BW)

BSC NAFEC RWY 8 DATE : 04/13/77 START TIME 14:03
AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
THEOD SS ACFT: DC-6 RUN: 0 DEG RAD 2K FT AC ANT 300 DEG



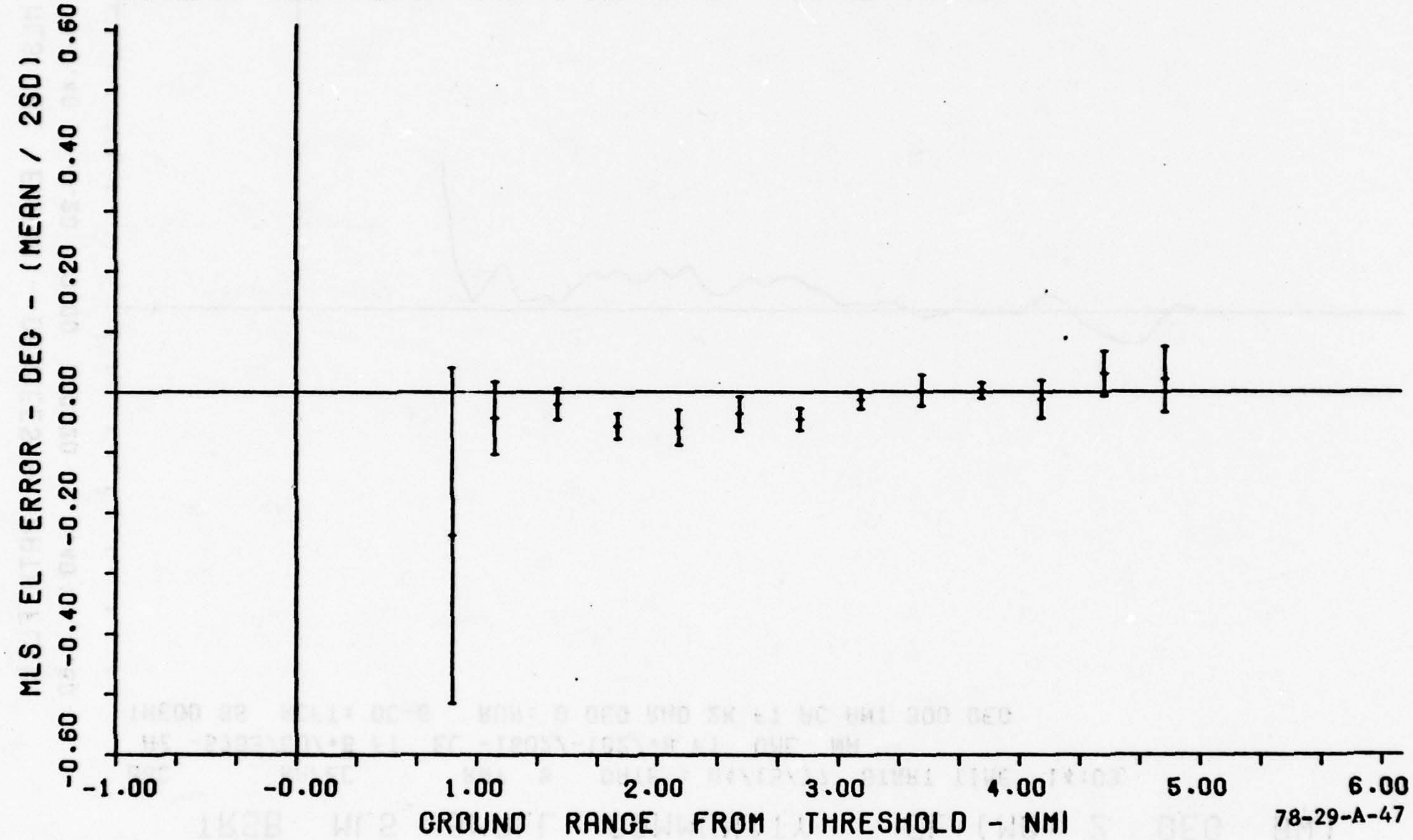
78-29-A-45



TRSB MLS SMALL COMMUNITY EL (MO: 2 DEG BW)
BSC NAFEC RWY 8 DATE : 04/13/77 START TIME 14:03
AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
THEOD SS ACFT: DC-6 RUN: 0 DEG RAD 2K FT AC ANT 300 DEG
MLS EL ERROR - DEGREES - (RAW)
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-1.00
-0.00
1.00
2.00
3.00
4.00
5.00
6.00
GROUND RANGE FROM THRESHOLD - NMI
78-29-A-46

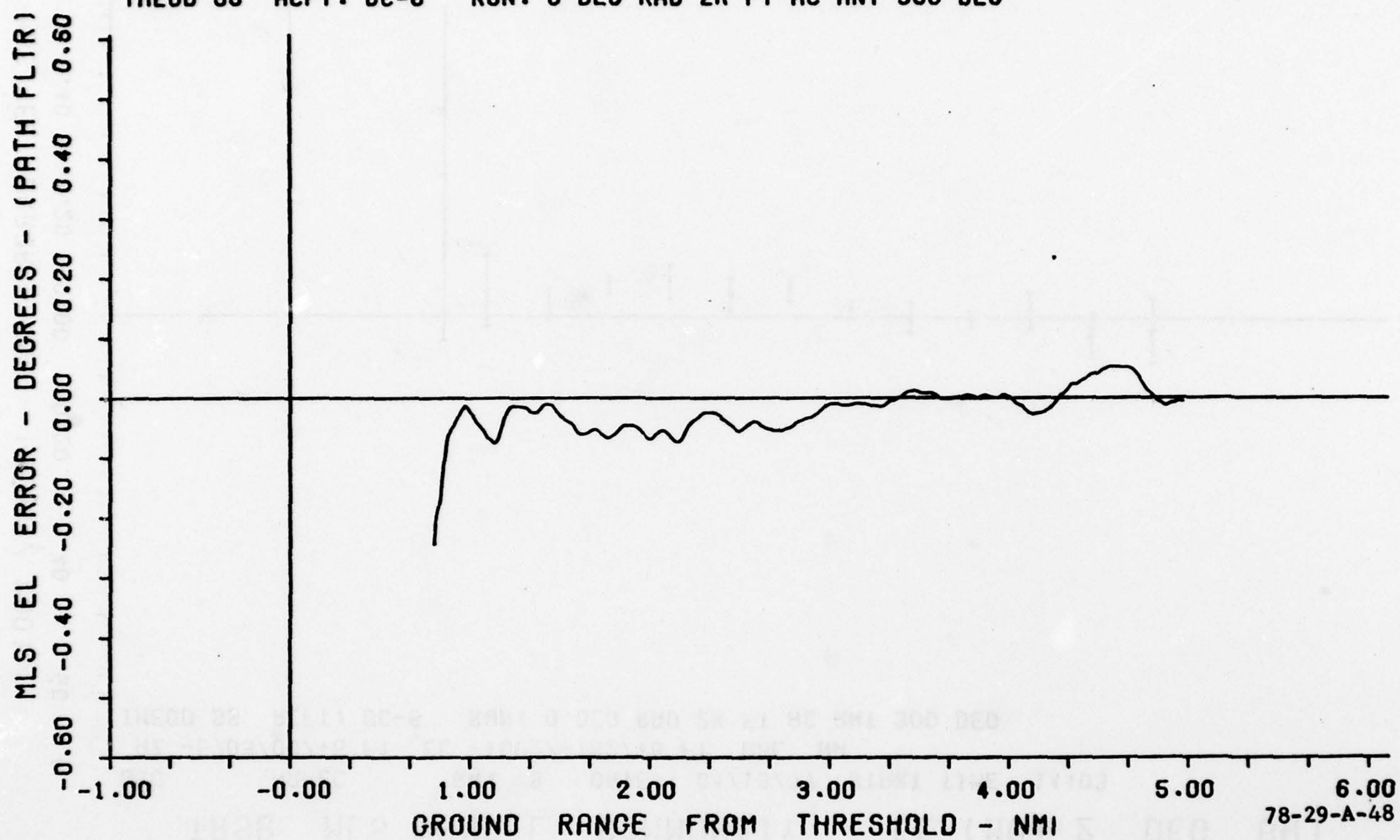
TRSB MLS SMALL COMMUNITY EL (MO: 2 DEG BW)

BSC NAFEC RWY 8 DATE : 04/13/77 START TIME 14:03
AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
THEOD SS ACFT: DC-6 RUN: 0 DEG RAD 2K FT AC ANT 300 DEG



TRSB MLS SMALL COMMUNITY EL (MO: 2 DEG BW)

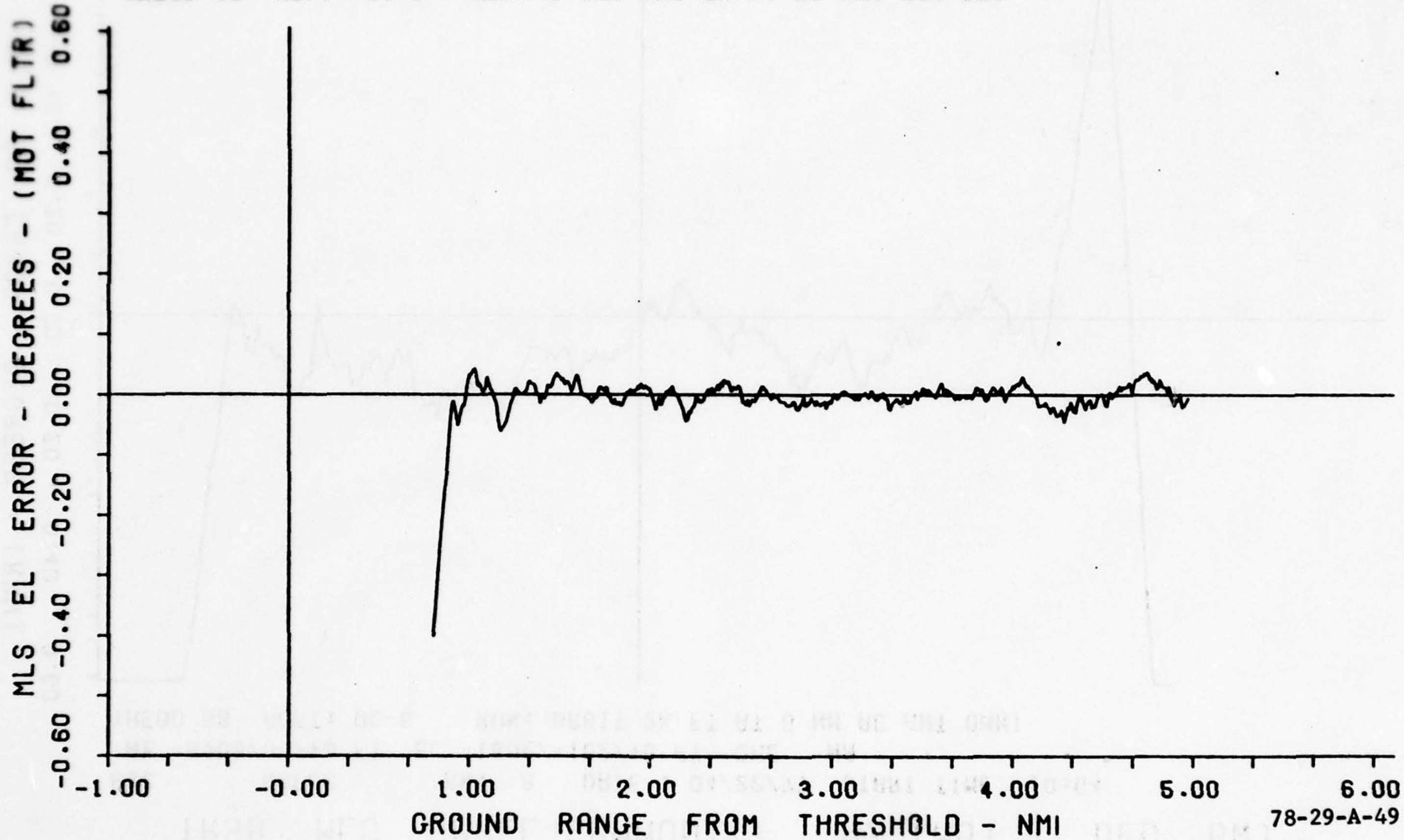
BSC NAFEC RWY 8 DATE : 04/13/77 START TIME 14:03
AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
THEOD SS ACFT: DC-6 RUN: 0 DEG RAD 2K FT AC ANT 300 DEG



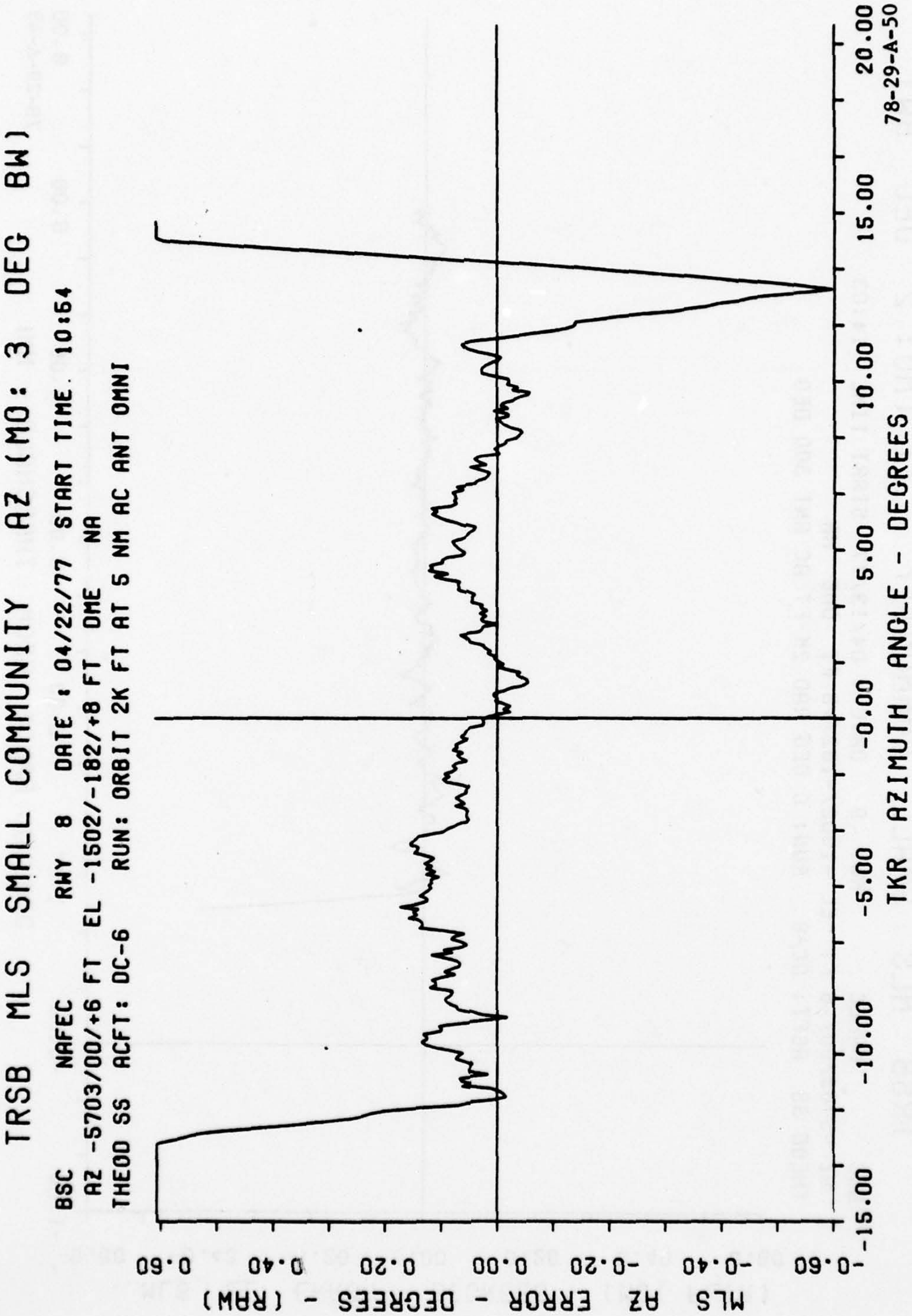
78-29-A-48

TRSB MLS SMALL COMMUNITY EL (MO: 2 DEG BW)

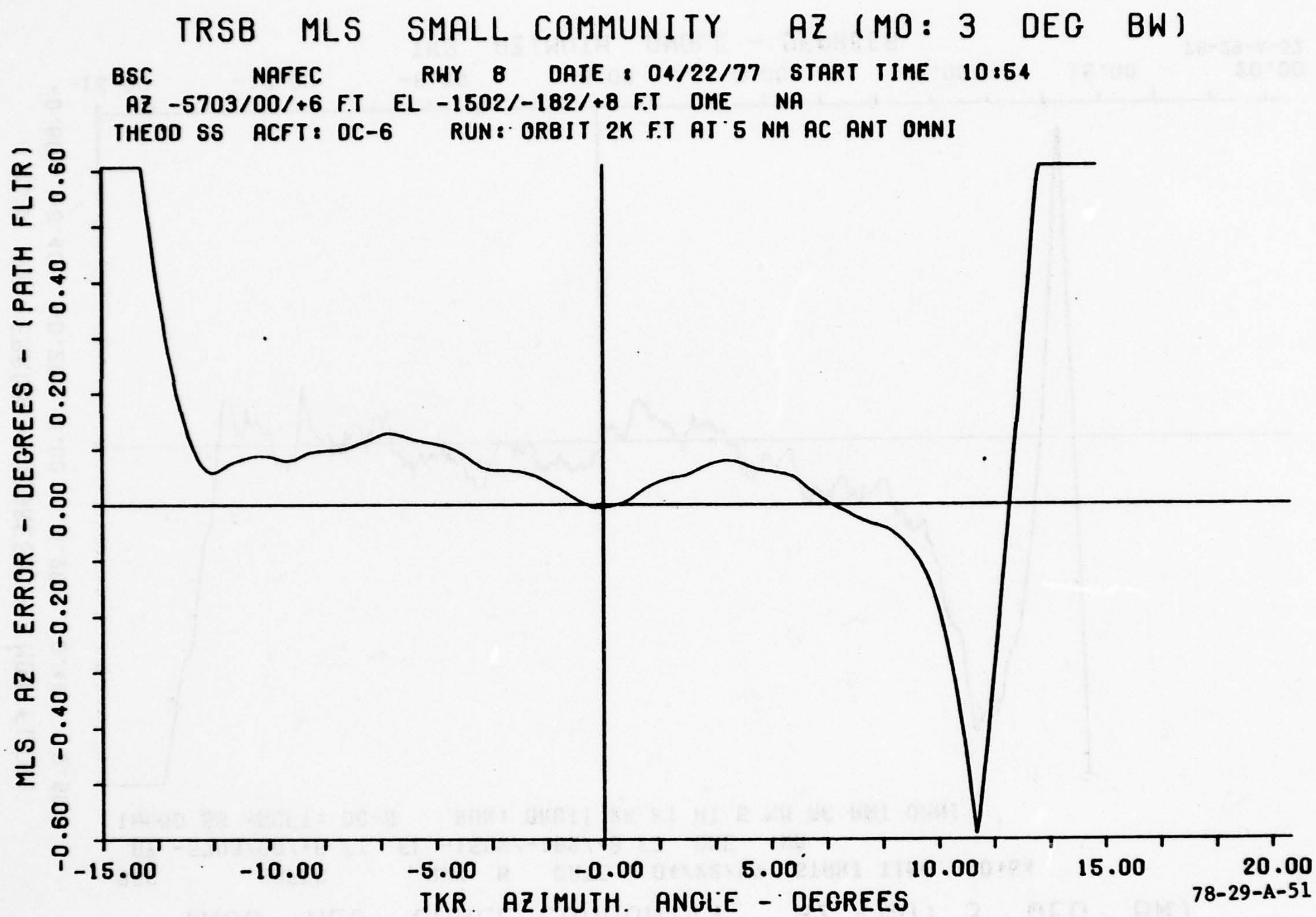
BSC NAFEC RWY 8 DATE : 04/13/77 START TIME 14:03
AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
THEOD SS ACFT: DC-6 RUN: 0 DEG RAD 2K FT AC ANT 300 DEG



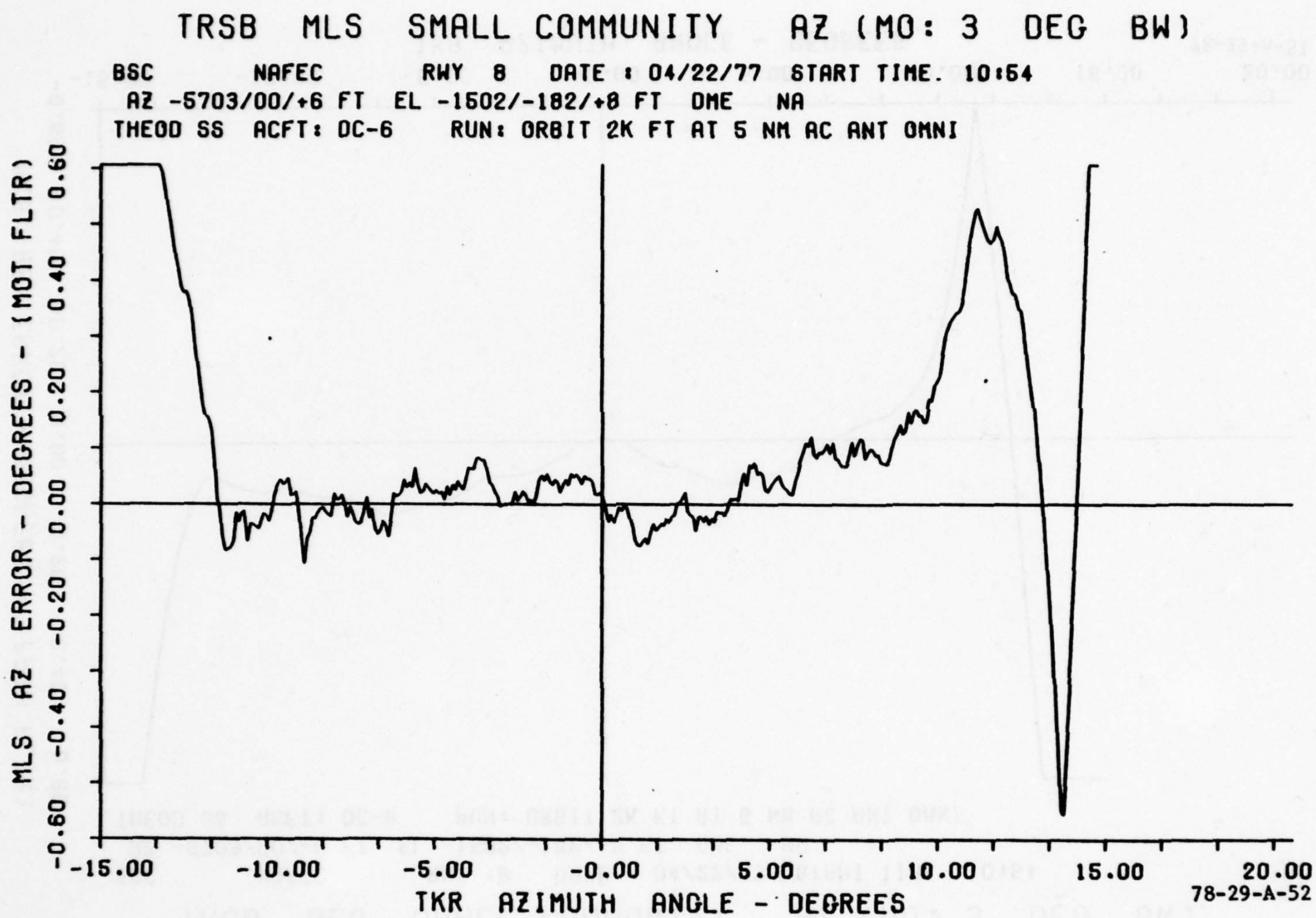
78-29-A-49



TRSB MLS SMALL COMMUNITY AZ (MO: 3 DEG BW)
BSC NAFEC RWY 8 DATE : 04/22/77 START TIME 10:54
AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
THEOD SS ACFT: DC-6 RUN: ORBIT 2K FT AT 5 NM AC ANT OMNI
MLS AZ ERROR - DEGREES - (RAW)
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-15.00
-10.00
-5.00
-0.00
5.00
10.00
15.00
20.00
TKR AZIMUTH ANGLE - DEGREES
78-29-A-50

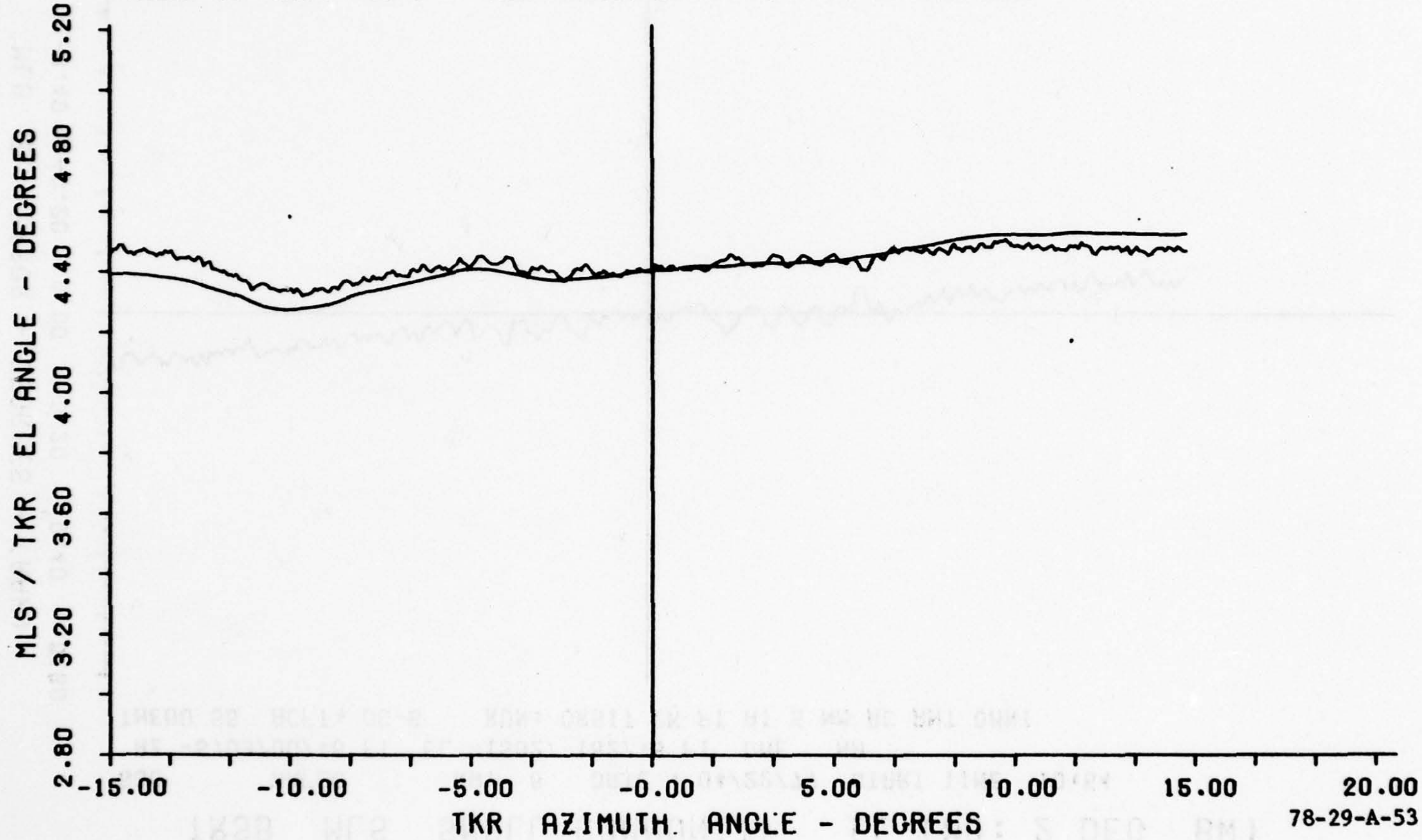


TRSB MLS SMALL COMMUNITY AZ (MO: 3 DEG BW)
BSC NAFEC RWY 8 DATE : 04/22/77 START TIME 10:54
AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
THEOD SS ACFT: DC-6 RUN: ORBIT 2K FT AT 5 NM AC ANT OMNI
MLS AZ ERROR - DEGREES - (PATH FLTR)
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-15.00
-10.00
-5.00
-0.00
5.00
10.00
15.00
20.00
TKR. AZIMUTH. ANGLE - DEGREES
78-29-A-51


TRSB MLS SMALL COMMUNITY AZ (MO: 3 DEG BW)
BSC NAFEC RWY 8 DATE : 04/22/77 START TIME. 10:54
AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
THEOD SS ACFT: DC-6 RUN: ORBIT 2K FT AT 5 NM AC ANT OMNI
MLS AZ ERROR - DEGREES - (MOT FLTR)
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-15.00
-10.00
-5.00
-0.00
5.00
10.00
15.00
20.00
TKR AZIMUTH ANGLE - DEGREES
78-29-A-52

TRSB MLS SMALL COMMUNITY EL (MO: 2 DEG BW)

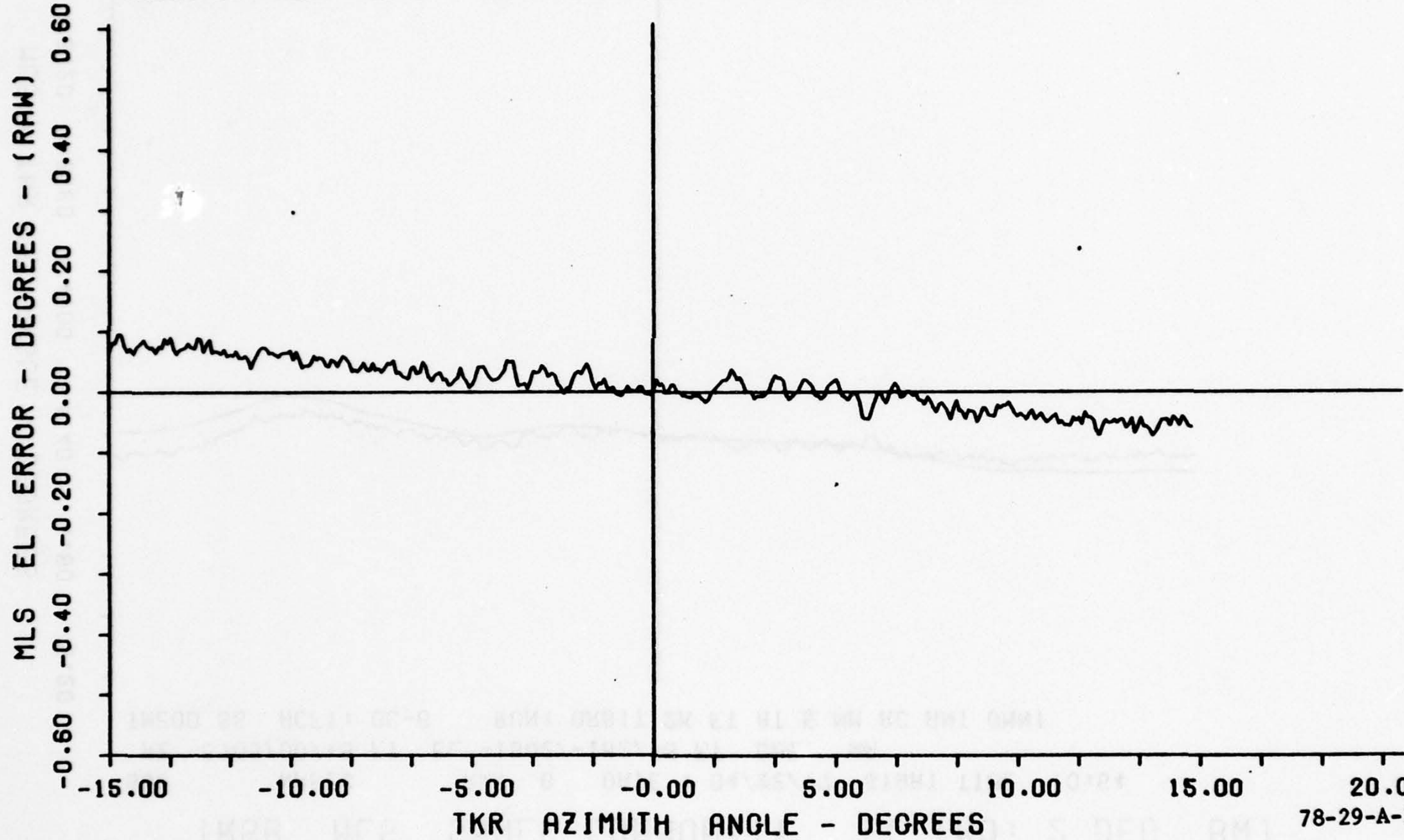
BSC NAFEC RWY 8 DATE : 04/22/77 START TIME 10:54
AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME. NA
THEOD SS ACFT: DC-6 RUN: ORBIT 2K FT AT 5 NM AC ANT OMNI



78-29-A-53

TRSB MLS SMALL COMMUNITY EL (MO: 2 DEG BW)

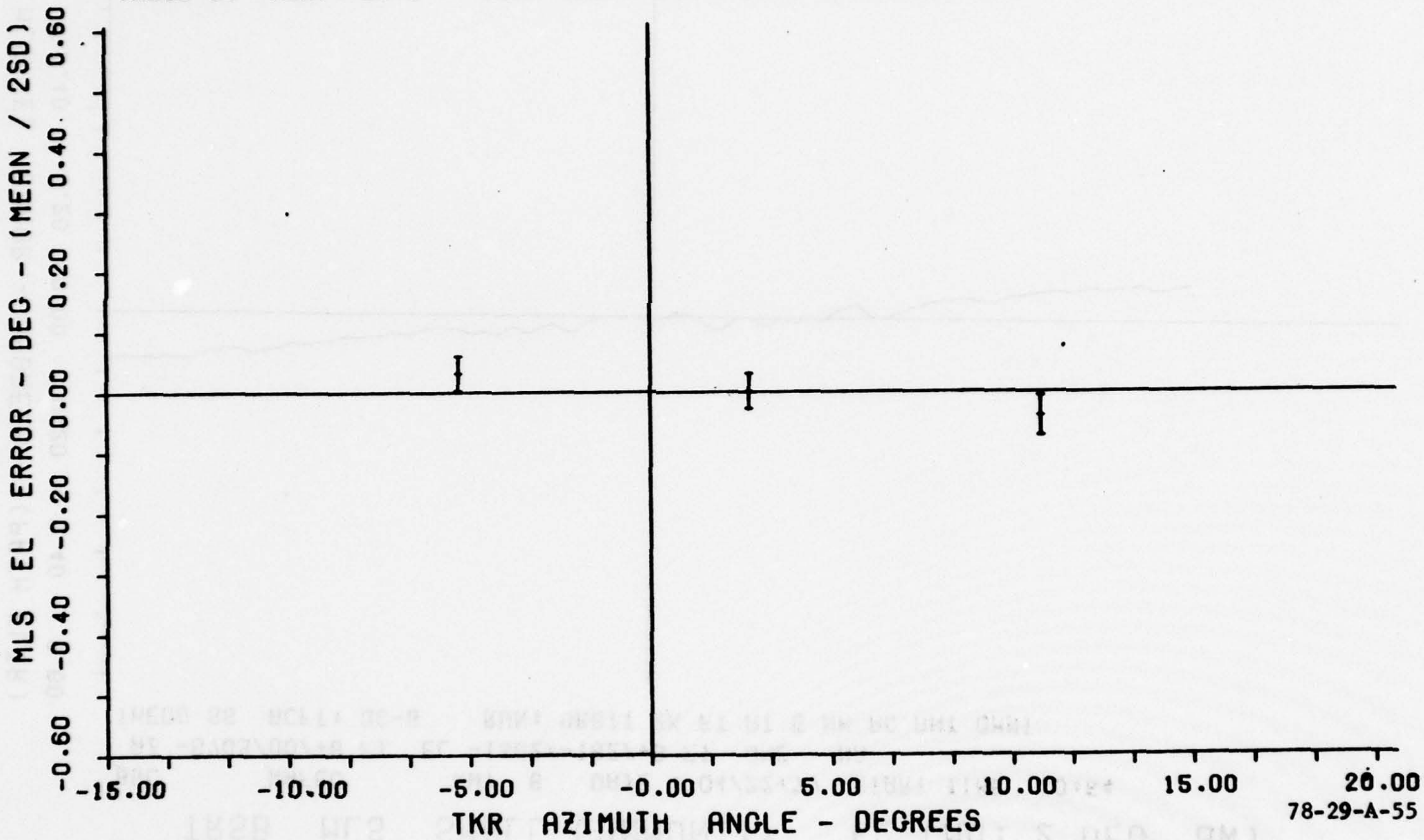
BSC NAFEC RWY 8 DATE : 04/22/77 START TIME 10:54
AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
THEOD SS ACFT: DC-6 RUN: ORBIT 2K FT AT 5 NM AC ANT OMNI



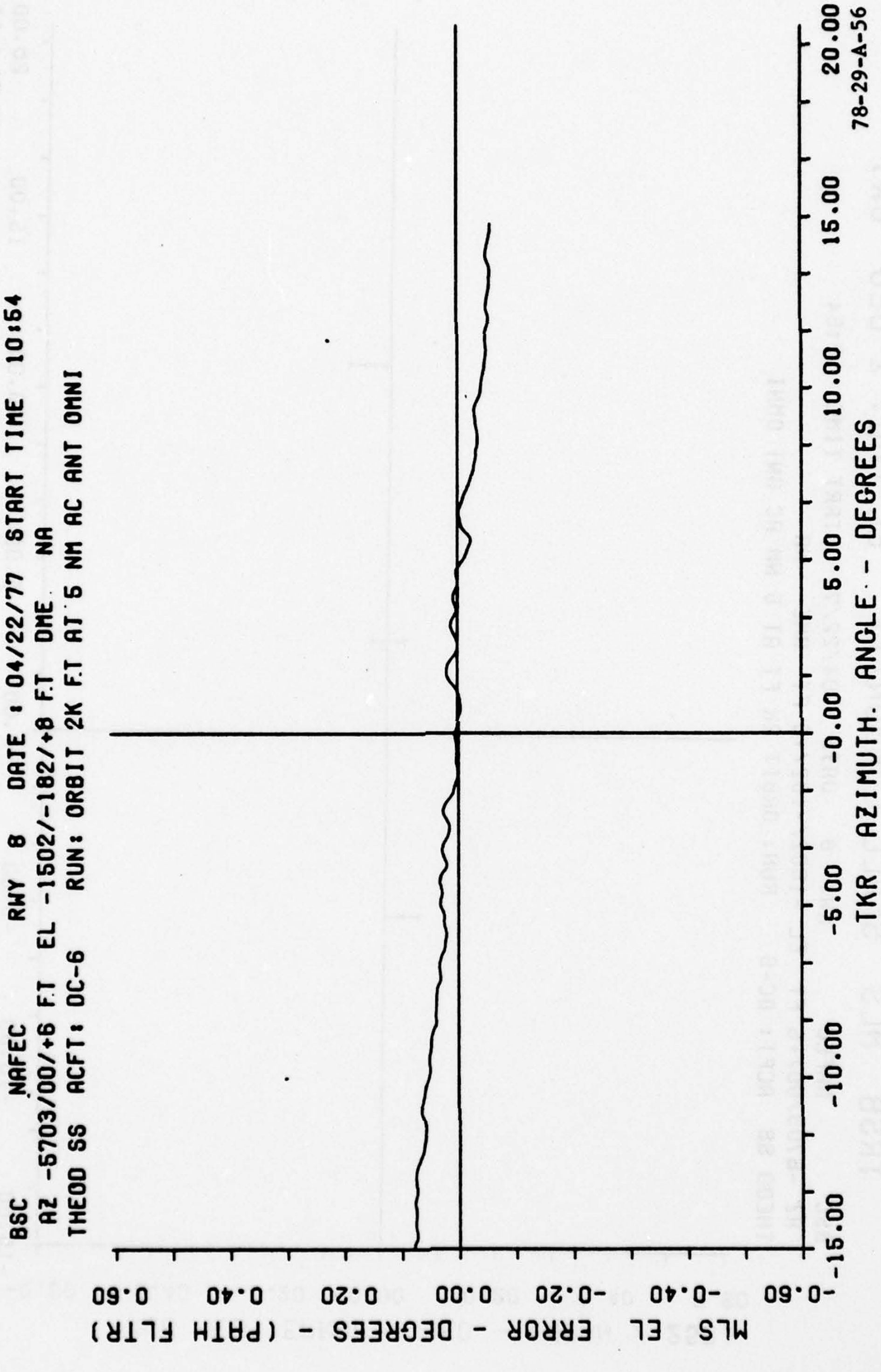
78-29-A-54

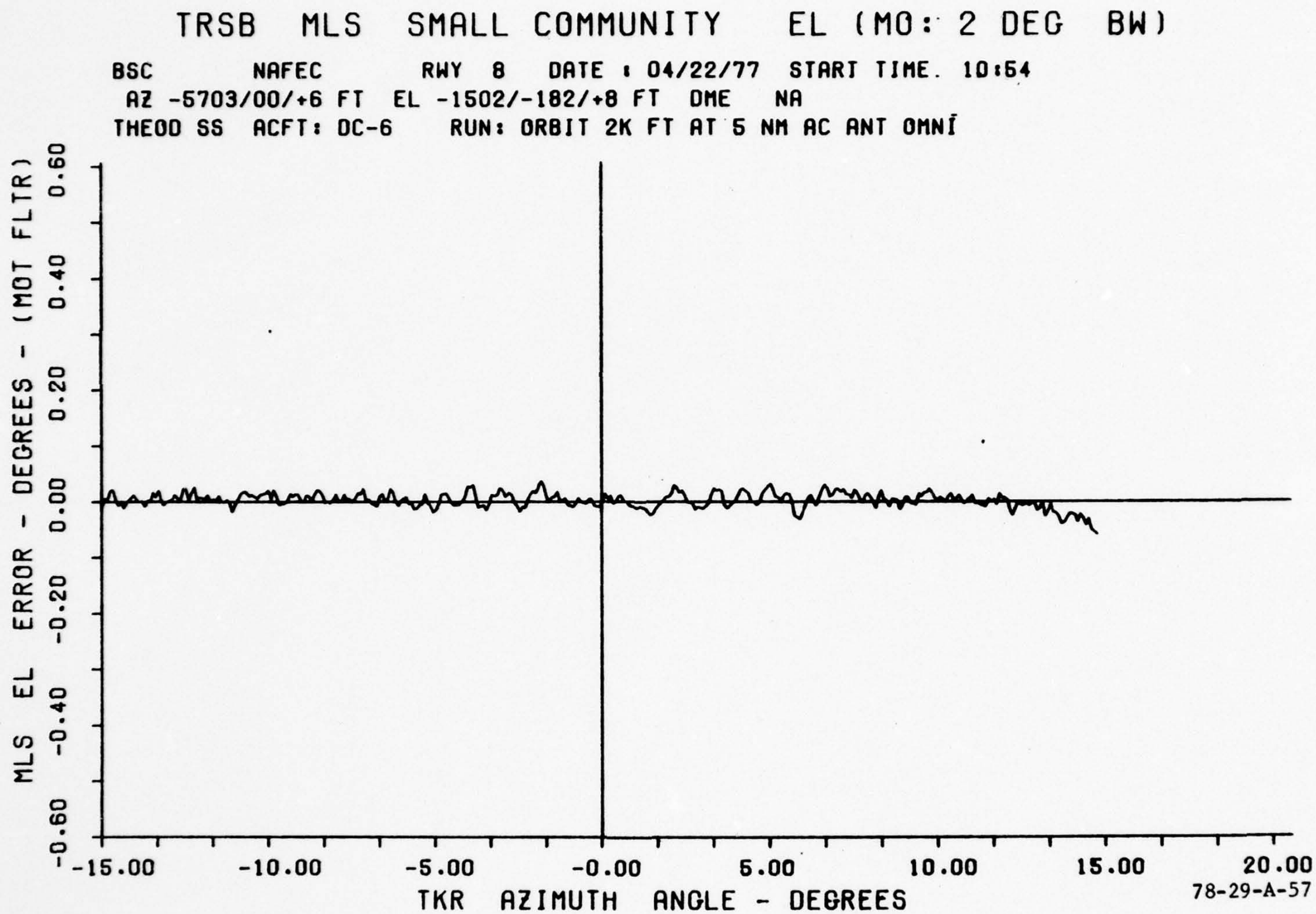
TRSB MLS SMALL COMMUNITY EL (MO: 2 DEG BW)

BSC NAFEC RWY 8 DATE : 04/22/77 START TIME 10:54
AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
THEOD SS ACFT: DC-6 RUN: ORBIT 2K FT AT 5 NM AC ANT OMNI



78-29-A-55


TRSB MLS SMALL COMMUNITY EL (MO: 2 DEG BW)
BSC NAFEC RWY 8 DATE : 04/22/77 START TIME 10:54
AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
THEOD SS ACFT: DC-6 RUN: ORBIT 2K FT AT 5 NM AC ANT OMNI
MLS EL ERROR - DEGREES - (PATH FLTR)
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
TKR AZIMUTH. ANGLE - DEGREES
-15.00
-10.00
-5.00
-0.00
5.00
10.00
15.00
20.00
78-29-A-56


TRSB MLS SMALL COMMUNITY EL (MO: 2 DEG BW)
BSC NAFEC RWY 8 DATE : 04/22/77 START TIME. 10:54
AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
THEOD SS ACFT: DC-6 RUN: ORBIT 2K FT AT 5 NM AC ANT OMNI
MLS EL ERROR - DEGREES - (MOT FLTR)
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-15.00
-10.00
-5.00
-0.00
5.00
10.00
15.00
20.00
TKR AZIMUTH ANGLE - DEGREES
78-29-A-57

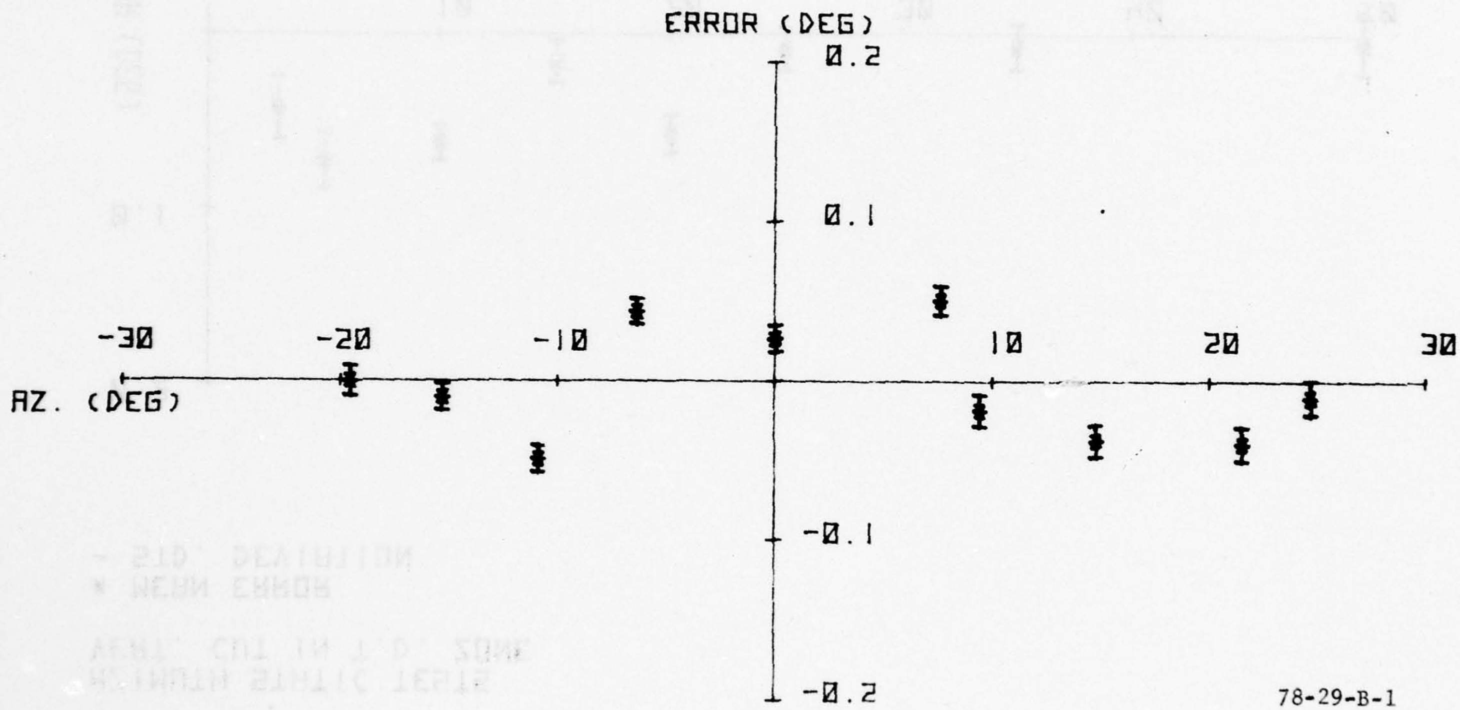
APPENDIX B

STATIC DATA

TRSB BENDIX BASIC NARROW

AZIMUTH STATIC TESTS
CROSS-CUT AT POLE HT = 50 FT AGL
RANGE FROM AZIMUTH ANTENNA = 1870 FT

* MEAN ERROR
\- STD DEVIATION

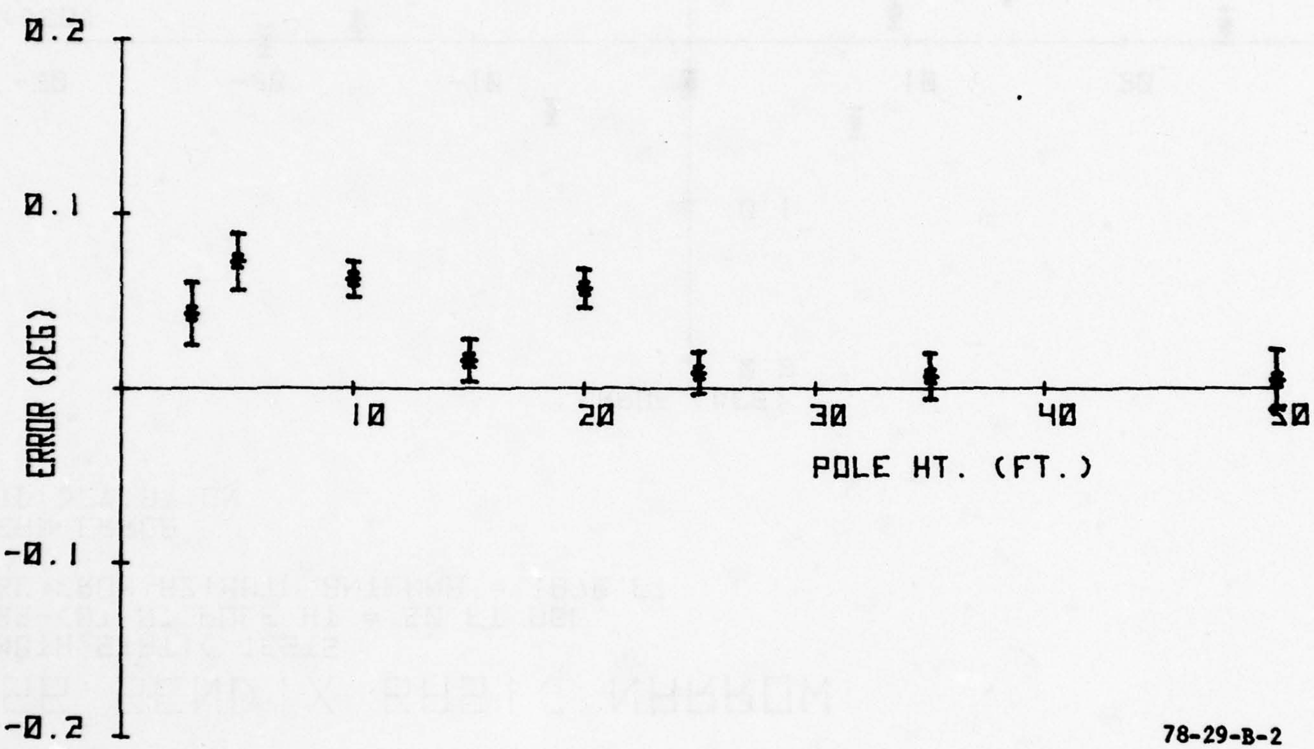


78-29-B-1

TRSB BENDIX BASIC NARROW

AZIMUTH STATIC TESTS
VERT. CUT IN T.D. ZONE

* MEAN ERROR
\- STD. DEVIATION

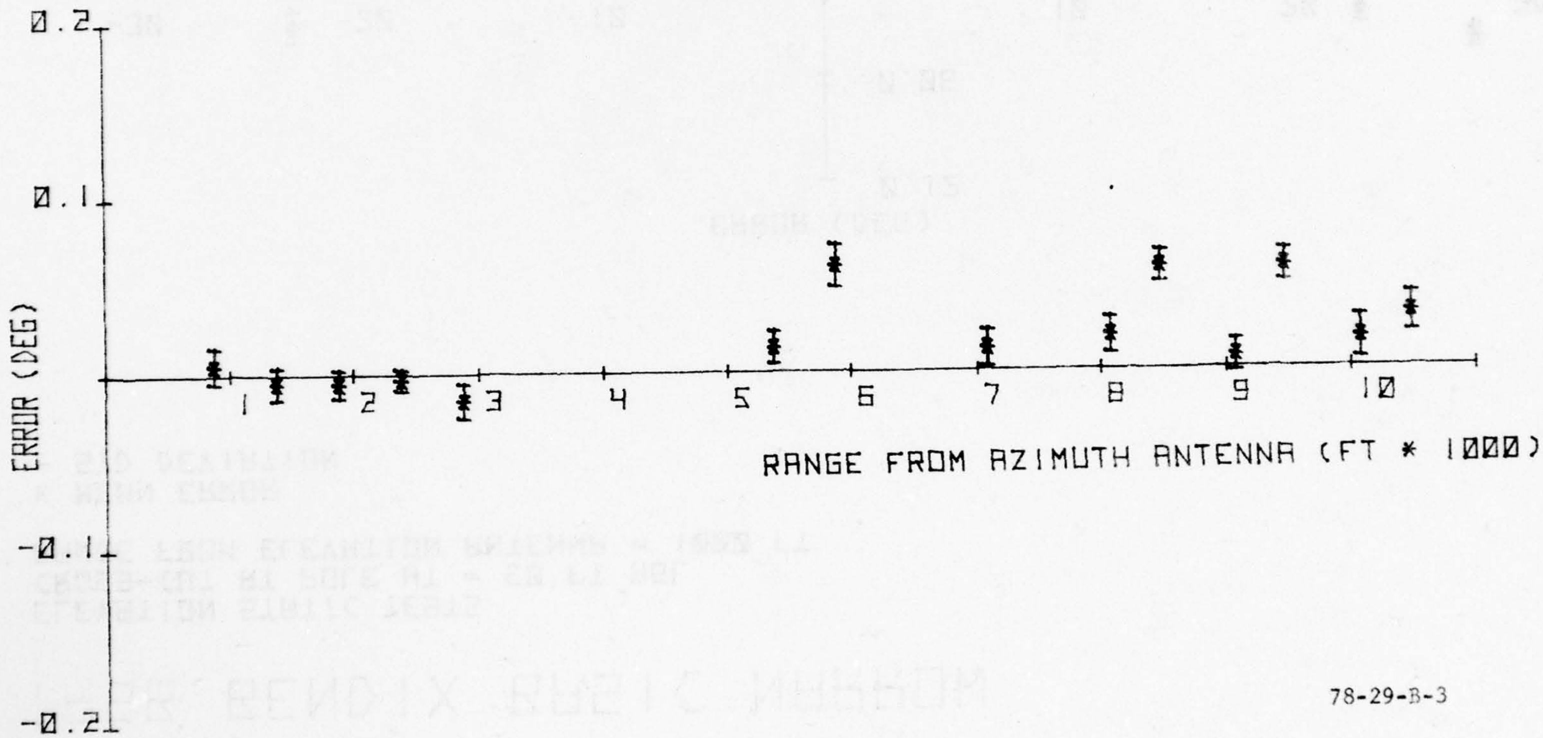


78-29-B-2

TRSB BENDIX BASIC NARROW

AZIMUTH STATIC TESTS
ALONG RWY C/L AT POLE HT.=15 FT. AGL.

* MEAN ERROR
- STD. DEVIATION

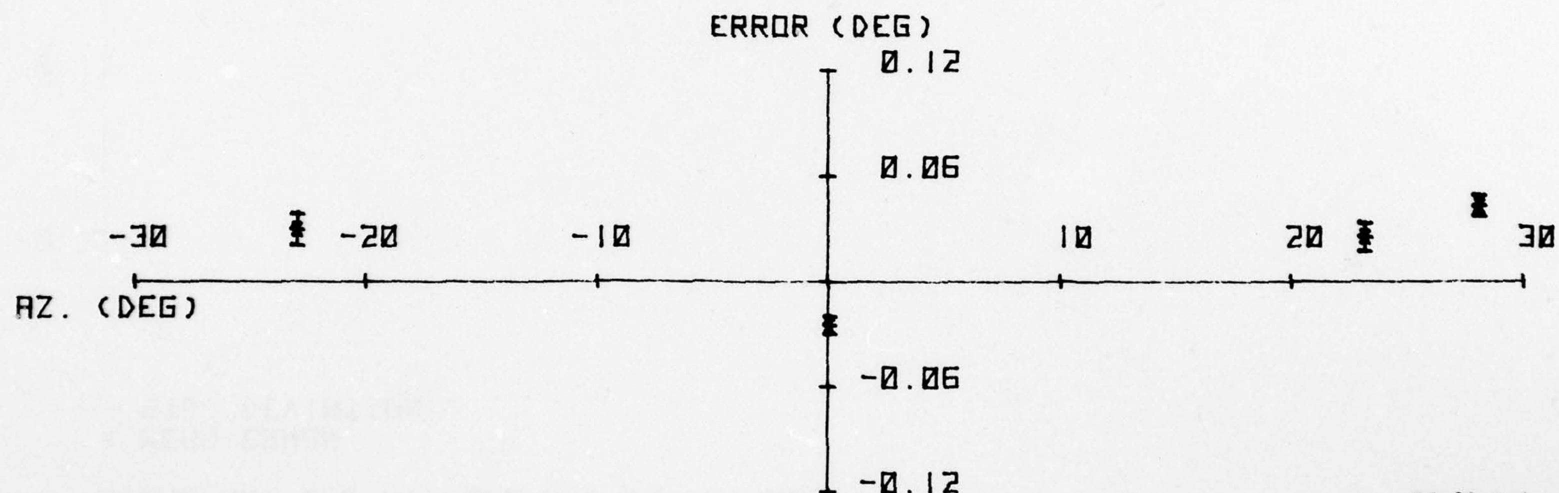


78-29-B-3

TRSB BENDIX BASIC NARROW

ELEVATION STATIC TESTS
CROSS-CUT AT POLE HT = 50 FT AGL
RANGE FROM ELEVATION ANTENNA = 1000 FT

* MEAN ERROR
- STD DEVIATION

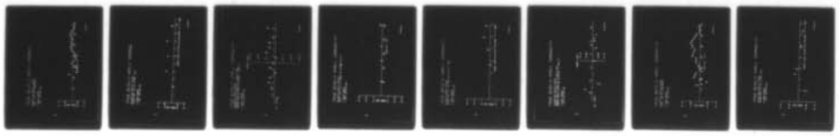


78-29-B-4

AD-A062 969 NATIONAL AVIATION FACILITIES EXPERIMENTAL CENTER ATL--ETC F/G 1/2
TEST AND EVALUATION OF PHASE III BENDIX BASIC NARROW AND SMALL --ETC(U)
NOV 78 C W MACKIN

UNCLASSIFIED FAA-NA-78-29 FAA-RD-78-127 NL

2 OF 2
AD
A062969

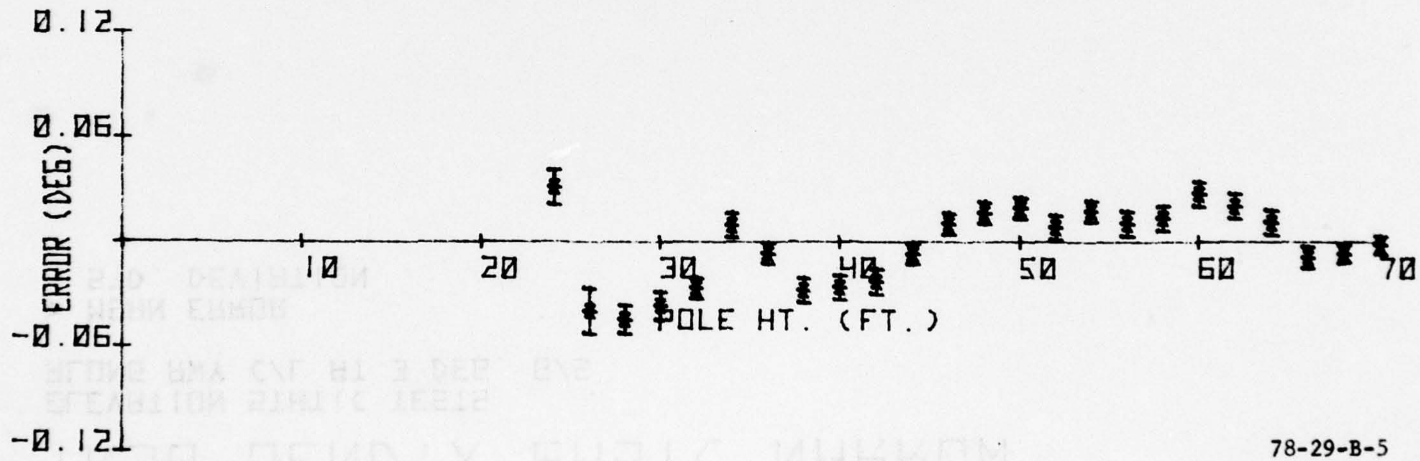


END
DATE
FILMED
3-79
DDC

TRSB BENDIX BASIC NARROW

ELEVATION STATIC TESTS
VERT. CUT AT THRESHOLD

* MEAN ERROR
- STD. DEVIATION

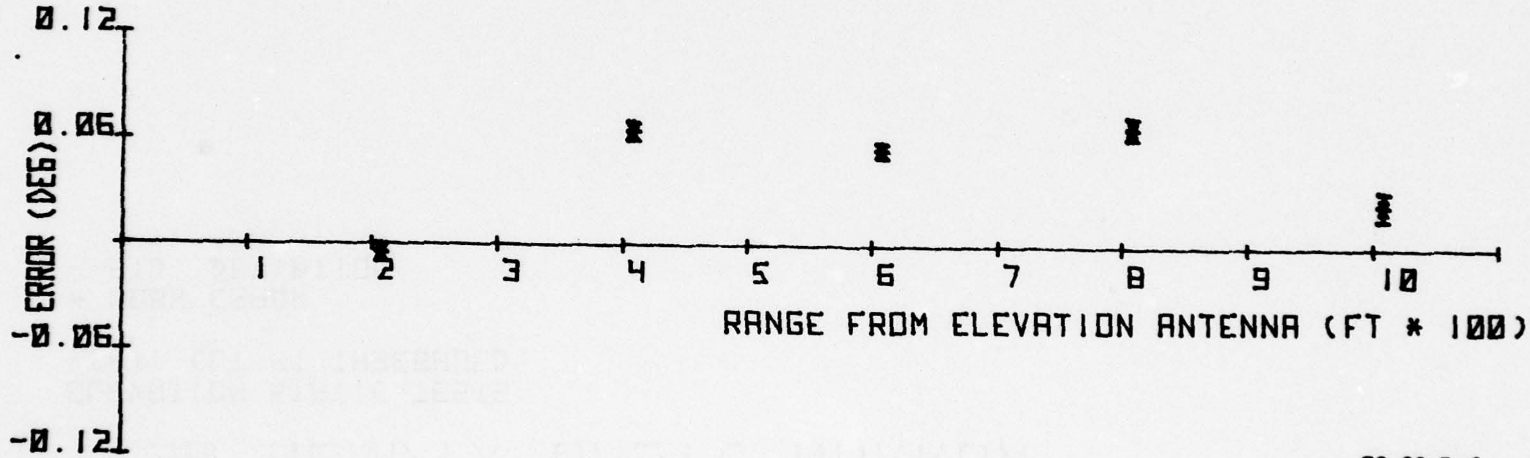


78-29-B-5

TRSB BENDIX BASIC NARROW

ELEVATION STATIC TESTS
ALONG RWY C/L AT 3 DEG. G/S

* MEAN ERROR
\- STD. DEVIATION

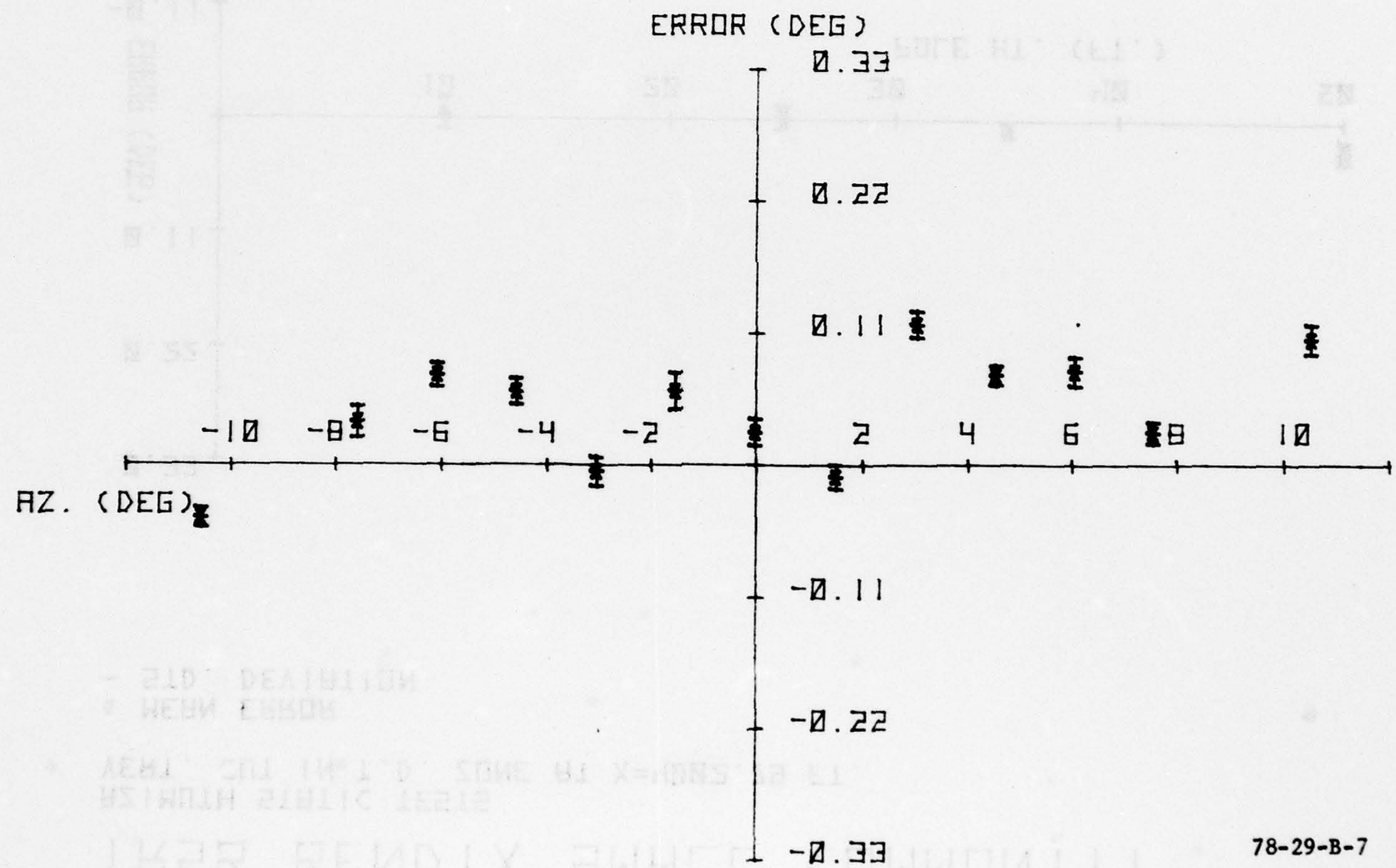


78-29-B-6

TRSB BENDIX SMALL COMMUNITY

AZIMUTH STATIC TESTS
CROSS-CUT AT POLE HT = 50 FT AGL
RANGE FROM AZIMUTH ANTENNA = 3760 FT

* MEAN ERROR
- STD DEVIATION

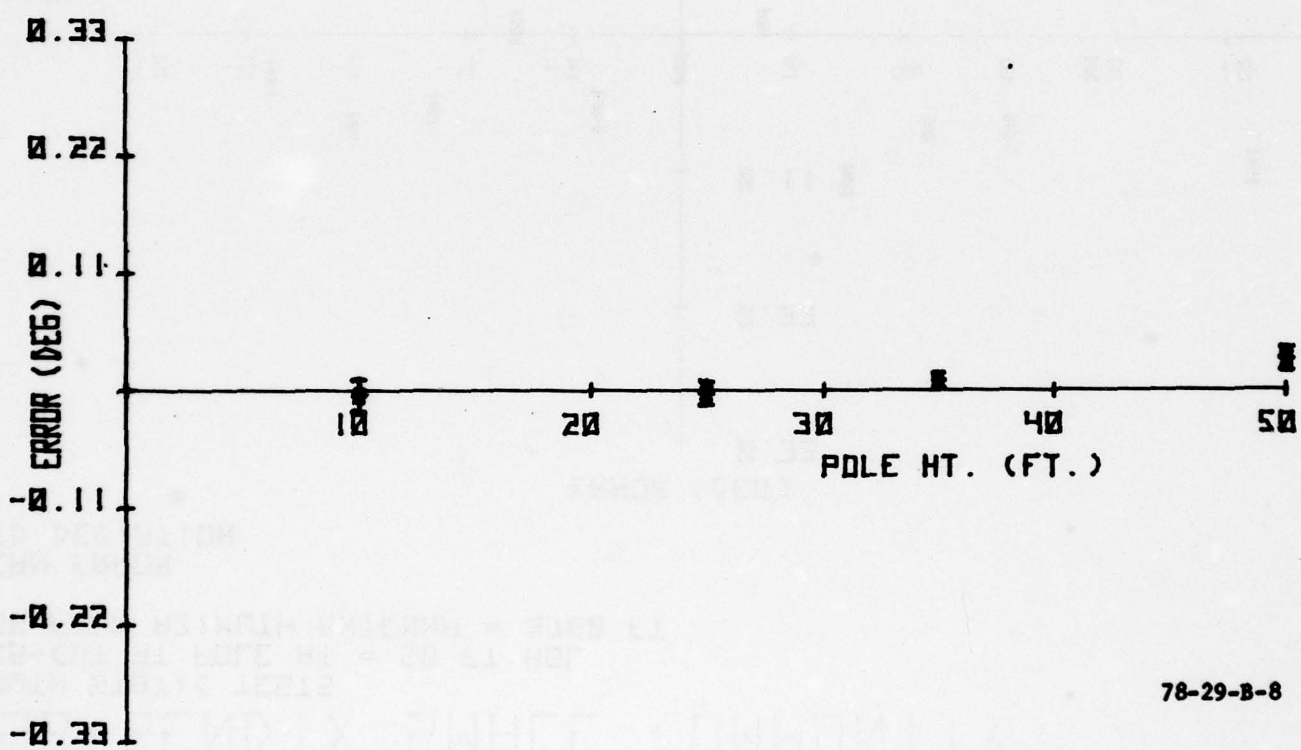


78-29-B-7

TRSB BENDIX SMALL COMMUNITY

AZIMUTH STATIC TESTS
VERT. CUT IN T.D. ZONE AT X=4002.79 FT.

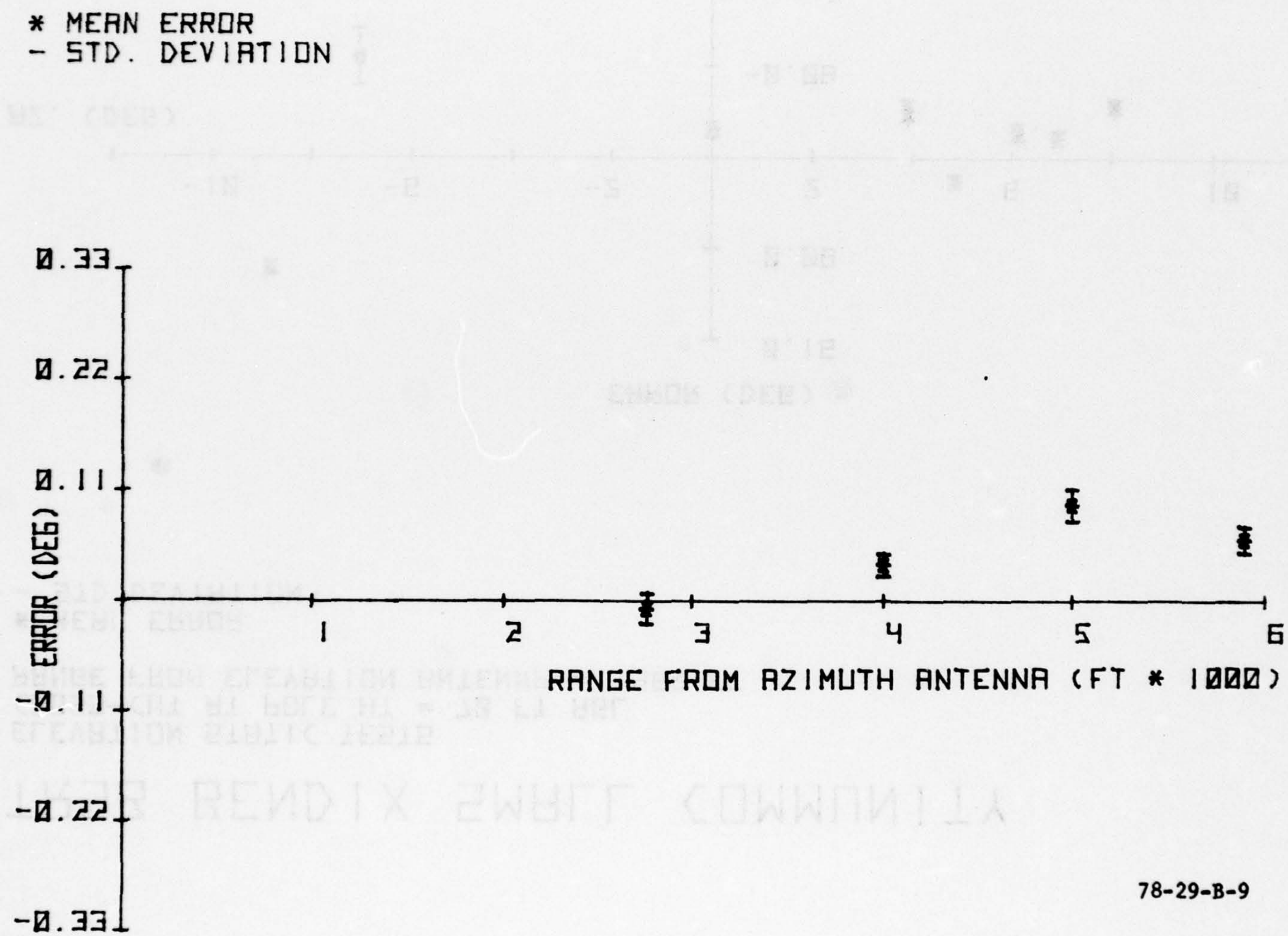
* MEAN ERROR
\- STD. DEVIATION



78-29-B-8

TRSB BENDIX SMALL COMMUNITY

AZIMUTH STATIC TESTS
ALONG RWY C/L AT POLE HT.=10 FT. AGL.

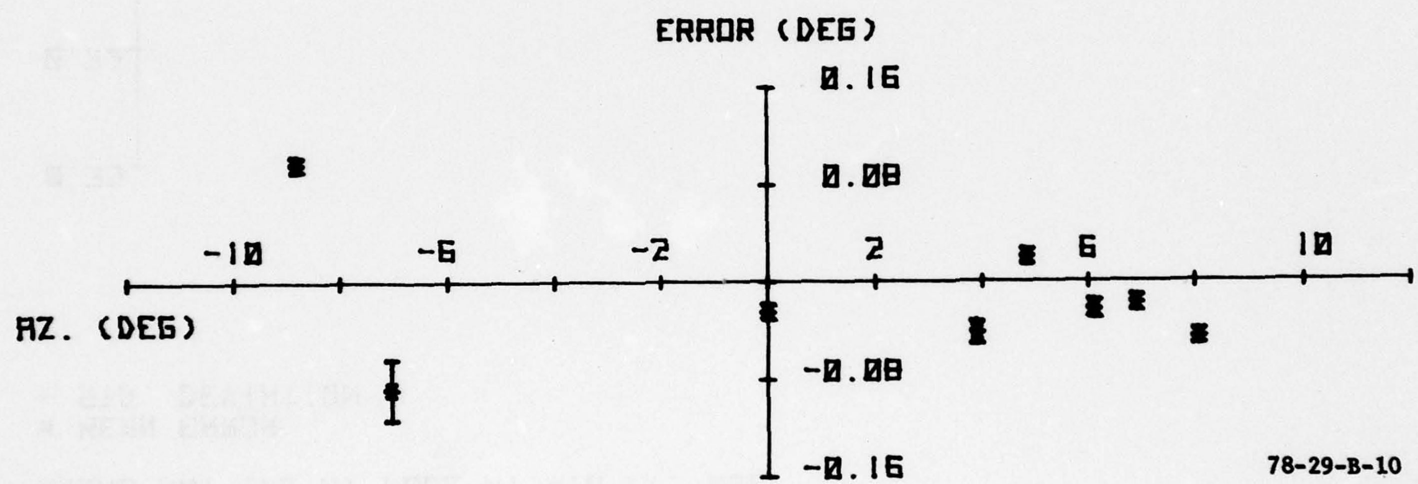


78-29-B-9

TRSB BENDIX SMALL COMMUNITY

ELEVATION STATIC TESTS
CROSS-CUT AT POLE HT = 70 FT AGL
RANGE FROM ELEVATION ANTENNA = 1465 FT

* MEAN ERROR
\- STD DEVIATION

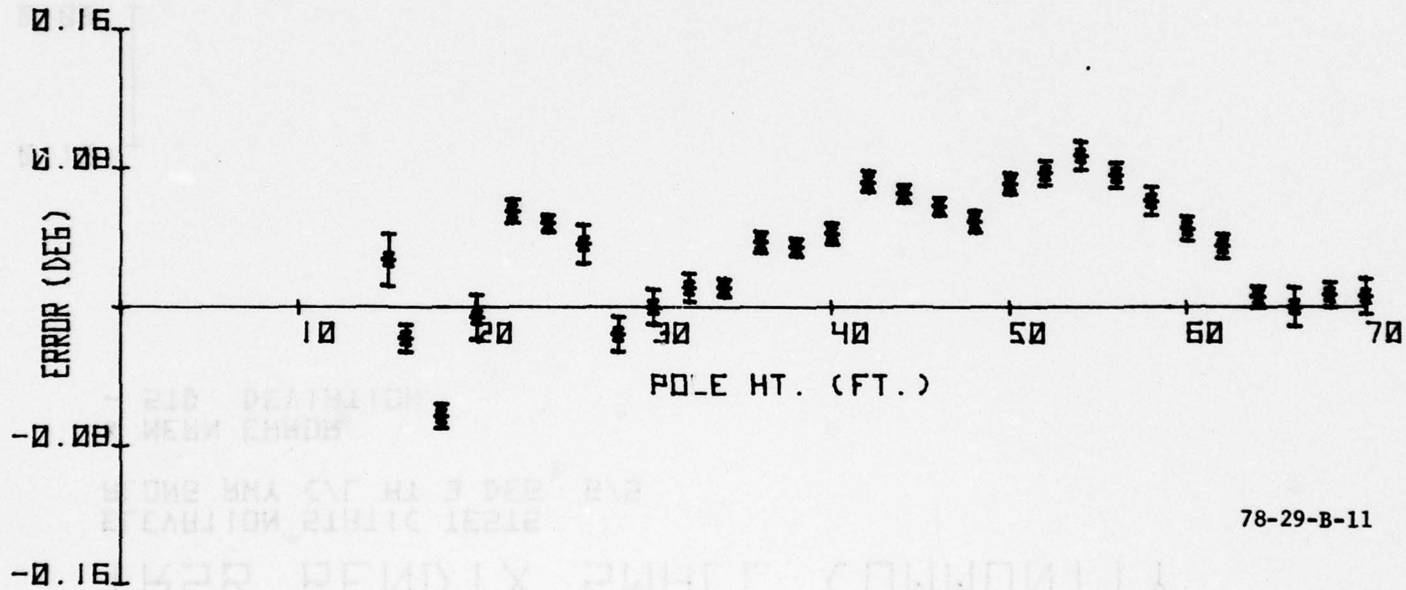


78-29-B-10

TRSB BENDIX SMALL COMMUNITY

ELEVATION STATIC TESTS
VERT. CUT AT THRESHOLD

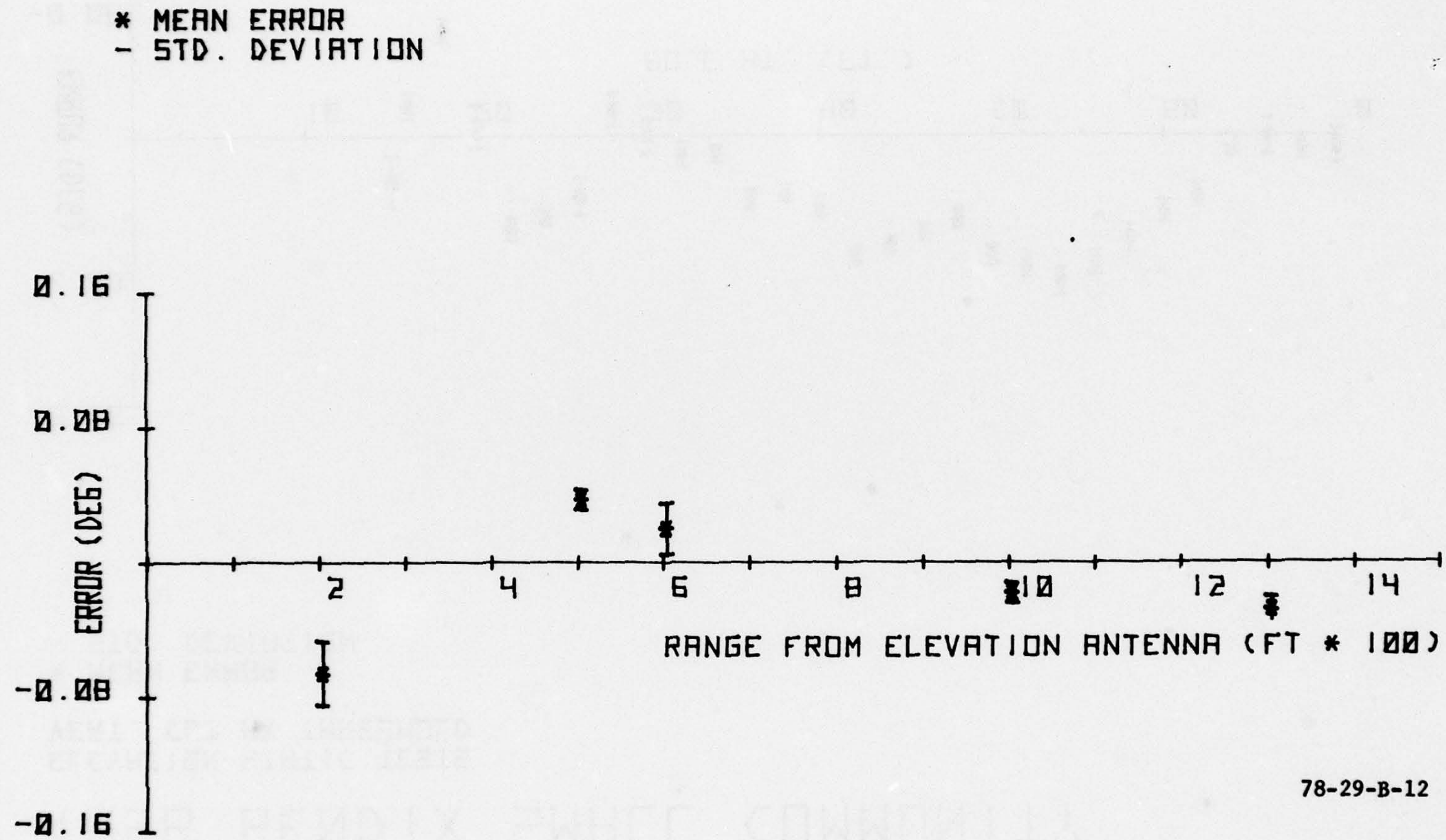
* MEAN ERROR
\- STD. DEVIATION



78-29-B-11

TRSB BENDIX SMALL COMMUNITY

ELEVATION STATIC TESTS
ALONG RWY C/L AT 3 DEG. G/S



78-29-B-12